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Rio Blanco
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REVEGETATION PROGRAM
1978 ANNUAL REPORT
March 9, 1979

VOLUME 1 OF 3-TEXT

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U. S. DEPARTMENT OF INTERIOR
OIL SHALE
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1978 ANNUAL REPORT

FOR

RBOSC REVEGETATION EXPERIMENTAL PROGRAM

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THE 1978 ANNUAL REPORT FOR
THE RBOSC REVEGETATION EXPERIMENTAL PROGRAM

Rio Blanco Oil Shale Company has completed the three-year revegetation experimental program initiated in July, 1975. This program was developed to investigate available revegetation technology and to determine the feasibility of successfully revegetating disturbances on Tract C-a expected to result from oil shale development activities. Two major types of disturbances were investigated--surface disturbances similar to that which would result from construction and disturbances which would result from disposal of processed shale. A demonstration of the reclamation feasibility of these two disturbance types must be accomplished prior to the 10th anniversary of approval of the Revised Detailed Development Plan as outlined in Section 11 of the lease stipulations.

The results of the experiments initiated in 1975 and 1976 are presented in the following sections. Section 1.0 presents data obtained at R_1 and R_2 during the third growing season (1978) and compares the 1976, 1977, and 1978 results. Section 2.0 presents the results of the second year studies at R_3 during 1978 and compares the 1977 and 1978 results. Section 3.0 presents an overall evaluation of the revegetation experimental program,recommendations for implementation of the technology developed through the program, and suggestions for further experimental study.

SECTION 1.0 REVEGETATION EXPERIMENTS INITIATED IN 1975

1.1 Objectives

The 1975 revegetation experiments were designed to investigate revegetation techniques for surface disturbances. The experiments investigate species adaptability, mulch type, timing of fertilizer application, and aspect. The specific objectives of the 1975 experiments were discussed in the 1976 Revegetation Annual Report (RBOSC 1977a).

1.2 Methods

The revegetation experiments initiated in 1975 are being conducted at two locations; R_1, located on a northwest exposure and R_2, located on a southeast exposure. A total of 16 treatments, with three replicates of each treatment, was applied at each site in a randomized block design. A detailed description of the methods used in the 1975 revegetation experiments was presented in Section 2.5.3.2 of Progress Report 4 (1975). Emergence density, survival density, and percent cover were measured during the first growing season (1976). Percent cover was measured during the second growing season (1977). Above-ground biomass and percent cover were measured during the third growing season (1978).

1.3 Results and Discussion

1.3.1 Percent Cover Data

Percent cover was measured at R_1 and R_2 during the Fall of 1978. The percent cover data for each of the four permanent subplots within a treatment plot at each location are presented in Appendix A-1.

A summary of the percent cover data for three replicates (blocks) of each treatment at each location is presented in Appendix A-2.

Vegetation has been successfully established at R_1 and R_2 (Figures 1-1 and 1-2, respectively). The most common grasses on R_1 were Luna pubescent wheatgrass (*Agropyron trichophorum*) and wheatgrass species (*Agropyron* species are *A. smithii* and *A. riparium*). On R_2, Indian ricegrass (*Oryzopsis hymenoides*) replaced wheatgrass species as the dominant grass species during 1978 (RBOSC 1978). Invader grasses e.g., crested wheatgrass (*A. cristatum*) and squirreltail (*Sitanion hystrix*) were more common on both R_1 and R_2 during 1978 than during the previous two years (RBOSC 1978).

Lewis flax (*Linum lewisii*) and Cicer milkvetch (*Astragalus cicer*) were the dominant planted forb species on both revegetation plots (Appendix A-2). These two species replaced yellow sweetclover (*Melilotus officinalis*) which was the dominant planted forb during the first and second growing seasons (RBOSC 1977a, 1978). This succession of forb species was expected since yellow sweetclover is a biennial plant species. The most abundant plant species on the revegetation plots was the invader forb, Russian thistle (*Salsola kali*). This species was introduced into the revegetation plots primarily by the use of straw mulch (RBOSC 1977a) and increased in percent cover substantially during the second growing season (RBOSC 1978).

Rabbitbrush species (*Chrysothamnus* species included *C. viscidiflorus* and *C. nauseosus*) were the most abundant shrubs on R_2 but sagebrush (*Artemisia tridentata*) was the dominant shrub on R_1 (Appendix A-2). Other common shrubs included winterfat (*Eurotia lanata*) and fourwing saltbush (*Atriplex canescens*).

The percent cover contributed by each plant species on R_1 and R_2 for 1976, 1977, and 1978 is summarized in Tables 1-1 and 1-2, respectively. Shrub species were the only species which increased substantially in percent cover over the three years with the exception of Luna pubescent wheatgrass on R_1 and Indian ricegrass on R_2. The most notable decrease in percent cover was that of Russian thistle on R_1.

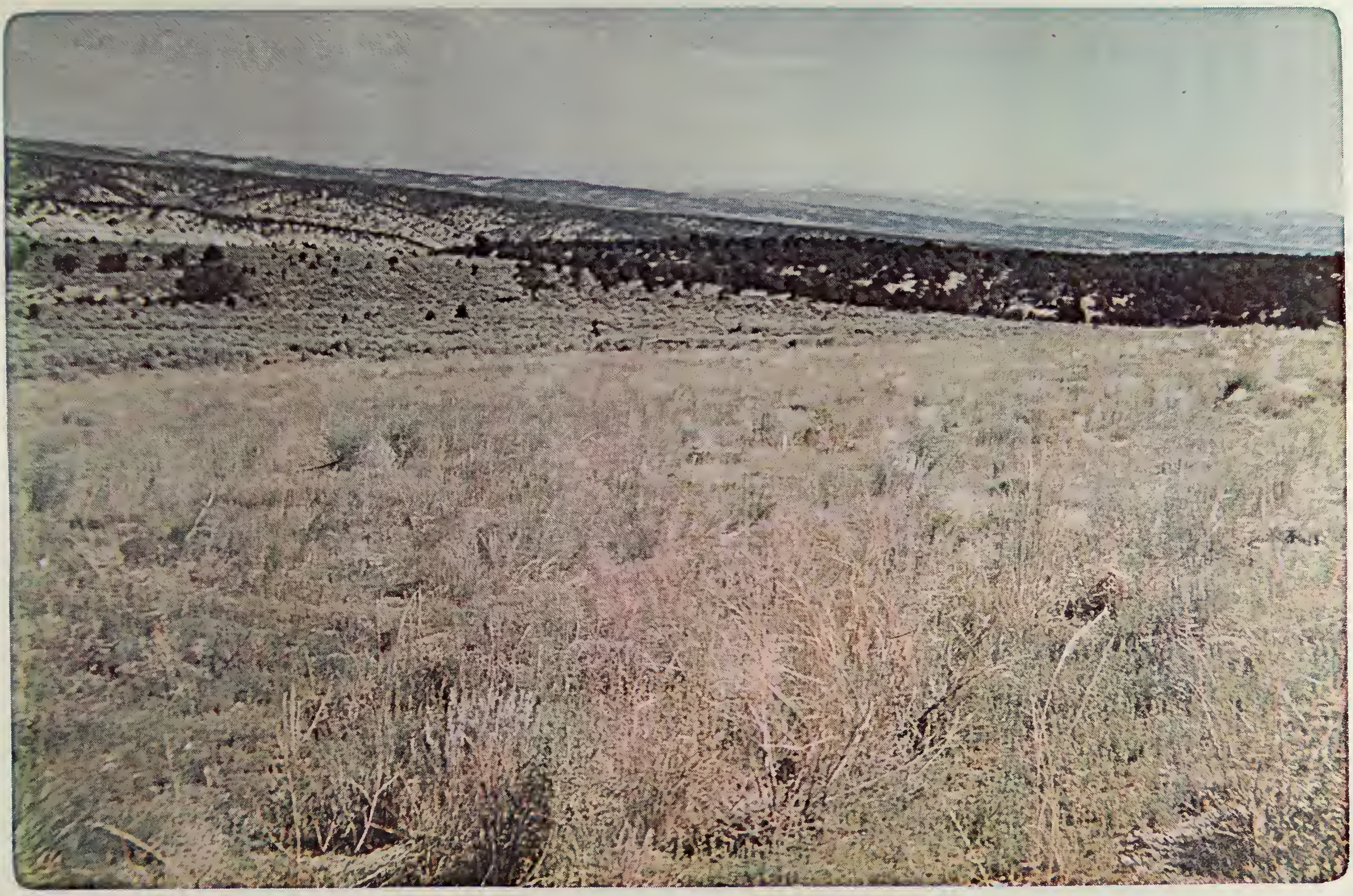


FIGURE 1-1. VIEW OF RBOSC REVEGETATION PLOT R_1 FROM THE SOUTHEAST CORNER OF THE PLOT.

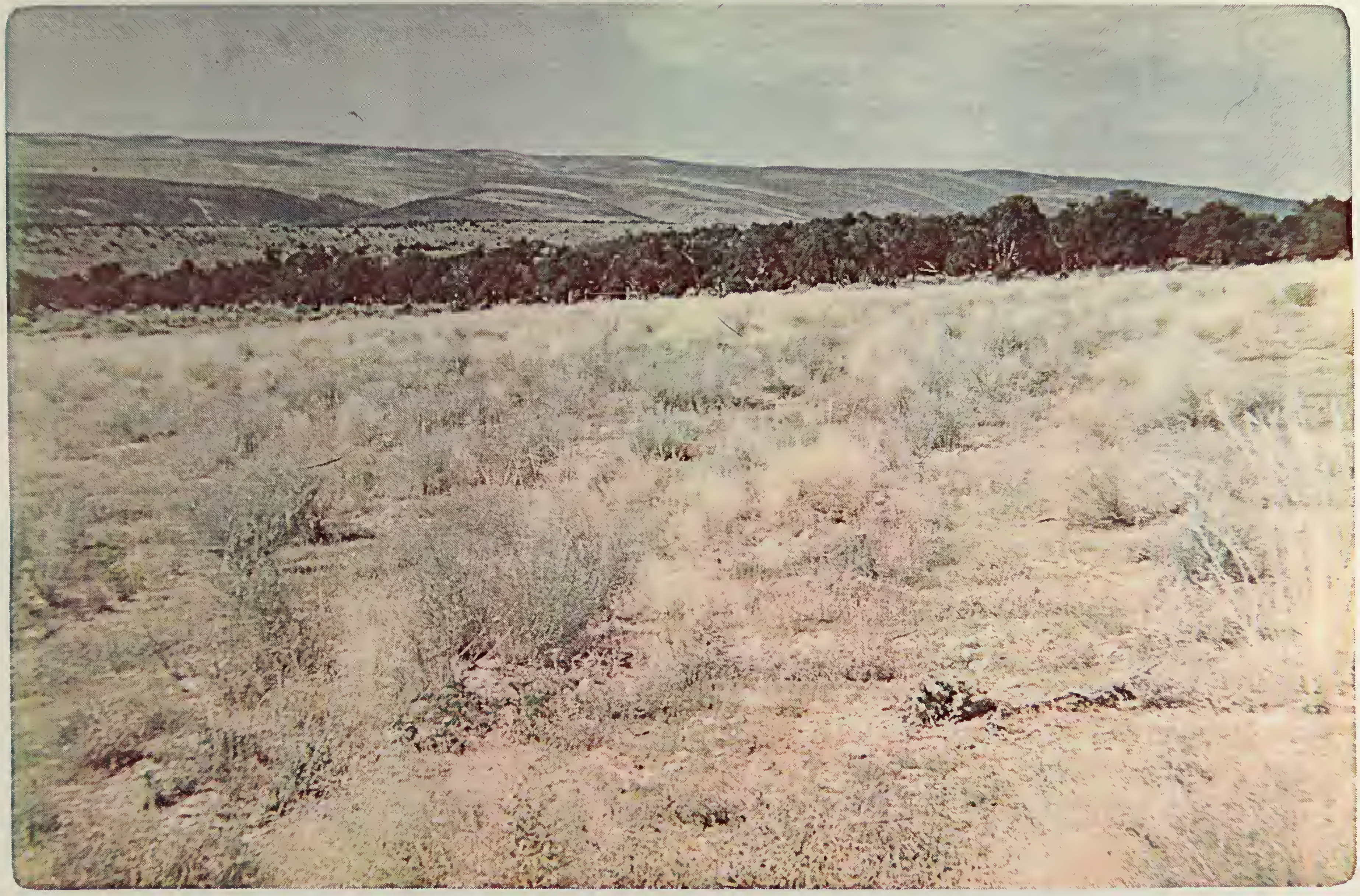


FIGURE 1-2. VIEW OF RBOSC REVEGETATION PLOT R_2 FROM THE NORTHWEST CORNER OF THE PLOT.

TABLE 1-1. AVERAGE PERCENT COVER OF PLANT SPECIES ON RBOSC REVEGETATION PLOT R_1 DURING FALL OF 1976,1977, and 1978

	1976	1977	1978
Grasses			
Hordeum vulgare	2.6	<0.1	---
Agropyron spp.	2.5	6.3	4.0
Agropyron smithii	1.2	0.4	---
Agropyron trichophorum	1.1	3.7	5.3
Stipa viridula	0.7	1.2	0.7
Oryzopsis hymenoides	0.6	0.6	0.9
Agropyron riparium	0.5	0.1	---
Others	<0.1	<0.1	0.5
Total Grass	9.3(33)*	12.5(29)*	11.4(28)*
Forbs			
Salsola kali	9.2	22.1	20.5
Melilotus officinalis	2.1	1.8	<0.1
Astragalus cicer	0.7	0.6	0.6
Penstemon strictus	0.7	0.6	0.2
Linum lewisii	0.6	1.0	1.1
Physaria floribunda	0.6	0.3	<0.1
Hedysarum utahensis	0.3	0.1	---
Ipomopsis aggregata	0.3	0.1	---
Senecio multilobatus	0.3	0.2	<0.1
Others	0.7	0.7	0.5
Total Forb	15.5(56)*	27.5(63)*	23.1(57)*
Shrubs			
Chrysothamnus spp	0.8	1.1	1.5
Eurotia lanata	0.7	1.1	1.0
Atriplex canescens	0.6	0.7	1.0
Purshia tridentata	0.5	0.2	0.1
Cercocarpus montanus	0.2	<0.1	<0.1
Artemisia tridentata	0.1	0.2	2.4
Pinus edulis	<0.1	---	---
Total Shrub	3.0(11)*	3.4 (8)*	6.1(15)*
Planted Species	14	20	19
Invaded Species	14	24	22
Total	28	44	41

---

* Number in parentheses is the percent represented by grasses, forbs, or shrubs for a given year.

TABLE 1-2. AVERAGE PERCENT COVER OF PLANT SPECIES ON RBOSC REVEGETATION PLOT R_2 DURING FALL OF 1976,1977, AND 1978

	1976	1977	1978
Grasses			
Hordeum vulgare	2.7	<0.1	---
Agropyron spp	1.9	3.6	2.6
Agropyron trichophorum	1.2	1.5	1.5
Oryzopsis hymenoides	1.1	2.5	3.5
Stipa viridula	0.8	1.0	0.6
Agropyron smithii	0.4	0.3	---
Agropyron riparium	0.1	0.1	---
Others	<0.1	0.1	0.4
Total Grasses	8.3 (42)*	9.2 (25)*	8.1 (30)*
Forbs			
Salsola kali	4.9	19.7	12.5
Melilotus officinalis	1.4	1.1	0.1
Penstemon strictus	0.7	0.6	0.3
Linum lewisii	0.7	1.0	1.1
Astragalus cicer	0.6	0.7	1.1
Senecio multilobatus	0.2	---	0.2
Physaria floribunda	0.2	0.1	<0.1
Hedysarum utahensis	0.1	0.1	<0.1
Ipomopsis aggregata	0.1	0.1	---
Others	0.6	1.2	0.3
Total Forbs	9.5 (47)*	24.6 (68)*	15.7 (53)*
Shrubs			
Chrysothamnus spp.	0.7	1.5	3.4
Purshia tridentata	0.4	0.4	0.5
Eurotia lantata	0.3	0.2	0.3
Atriplex canescens	0.2	0.3	0.4
Cercocarpus montanus	0.2	<0.1	<0.1
Artemisia tridentata	0.1	0.2	0.4
Rhus trilobata	<0.1	---	---
Pinus edulis	<0.1	---	---
Total Shrubs	2.1 (11)*	2.7 (7)*	5.1 (17)*
Planted Species	11	15	16
Invaded Species	9	21	14
Total	20	36	30

---

* Number in parentheses is the percent represented by grasses, forbs, or shrubs for a given year.

Rainfall received on the revegetation plots during the 1978 growing season (Table 1-3) was approximately half of that received during an equivalent period in 1977. The notable absence of late summer rains (Figure 1-3) during 1978 may be related to the decrease in Russian thistle since late summer rains are advantageous to the establishment of this species (Twisselmann 1967).

The percent cover of planted species did not change substantially at R_1 or R_2 during 1978 (20 to 19%; 15 to 16%, respectively) (Figure 1-4). Invaded species (primarily Russian thistle) decreased on both R_1 and R_2 and are responsible for the decrease in percent cover for total species (Figure 1-4).

A comparison of 1976, 1977, and 1978 percent cover by growth form indicates that forbs were the dominant vegetation life form on R_1 and R_2 (Figure 1-5). In contrast, grasses were most abundant on R_3. At all three locations, shrubs contributed more cover during 1978 than during preceding years. It is expected that as succession proceeds forbs, particularly weedy species such as Russian thistle, will be replaced by more desirable grasses and shrubs. The decrease in forb cover and increase in shrub cover during 1978 suggests that succession is progressing as expected on R_1 and R_2.

Vegetation baseline studies indicated that herbaceous cover in upland sagebrush varied from approximately 10 - 25 percent (RBOSC 1977b). Results for R_1 and R_2 (Tables 1-1 and 1-2, respectively) indicate that the reestablished vegetation has herbaceous cover which falls within that range found during baseline studies.

An Analysis of Variance (ANOVA) was performed to determine significant differences in percent cover among the mulch and fertilizer treatments. A detailed description of the statistical analyses and hypotheses tested was presented in the 1976 Revegetation Annual Report (RBOSC 1977a). The ANOVA was performed to test each plant species and group of plant species (e.g., grasses, forbs, invader species, etc.) at R_1 and R_2 with respect to percent cover. The results of the ANOVA for R_1 are presented in Appendix A-3; results for R_2 are presented in Appendix A-4.

For R_1, the ANOVA (Table 1-4) for percent cover indicates that no significant differences exist among mulches or among fertilizers but significant differences at the 0.01 level exist among plant species. A comparison of average percent

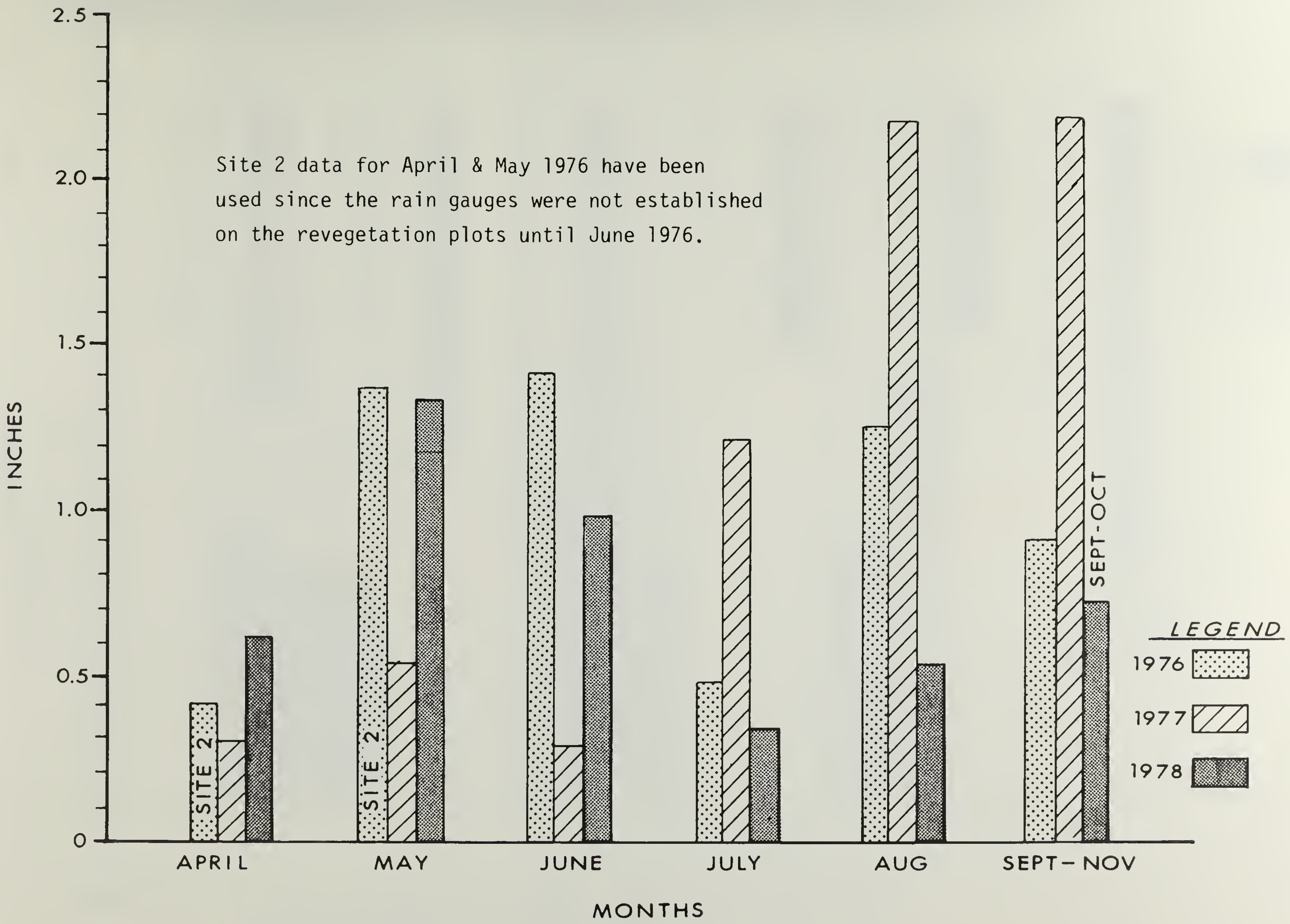
TABLE 1-3. RAINFALL (inches) RECORDED AT THE RBOSC REVEGETATION SITES (R_1, R_2, R_3) FROM APRIL THROUGH OCTOBER 1978.

	R_1		R_2		R_3		
DATE	STATION 1[1]	STATION 2[2]	STATION 1[1]	STATION 2[2]	STATION 1[1]	STATION 2[2]	AVERAGE
April	.62	.65	.64	.61	.64	.64	.63
May	1.36	1.46	1.28	1.57	1.22	1.37	1.38
June	1.19	1.03	1.00	1.03	.86	.82	.99
July	.27	.29	.26	.27	.27	.35	.37
August	.65	.68	.49	.60	.68	.69	.60
Sept. - Oct. 2	.49	.54	.56	.59	.64	.60	.57
Oct. 3 - Oct. 31	.20	.20	.20	.21	.20	.20	.20
TOTALS	4.78	4.85	4.43	4.88	4.51	5.17	4.74

---

[1] Upper Station

[2] Lower Station



Site 2 data for April & May 1976 have been used since the rain gauges were not established on the revegetation plots until June 1976.

FIGURE 1-3. PRECIPITATION MEASURED AT THE RBOSC REVEGETATION SITES DURING APRIL - NOVEMBER OF 1976, 1977 AND 1978.

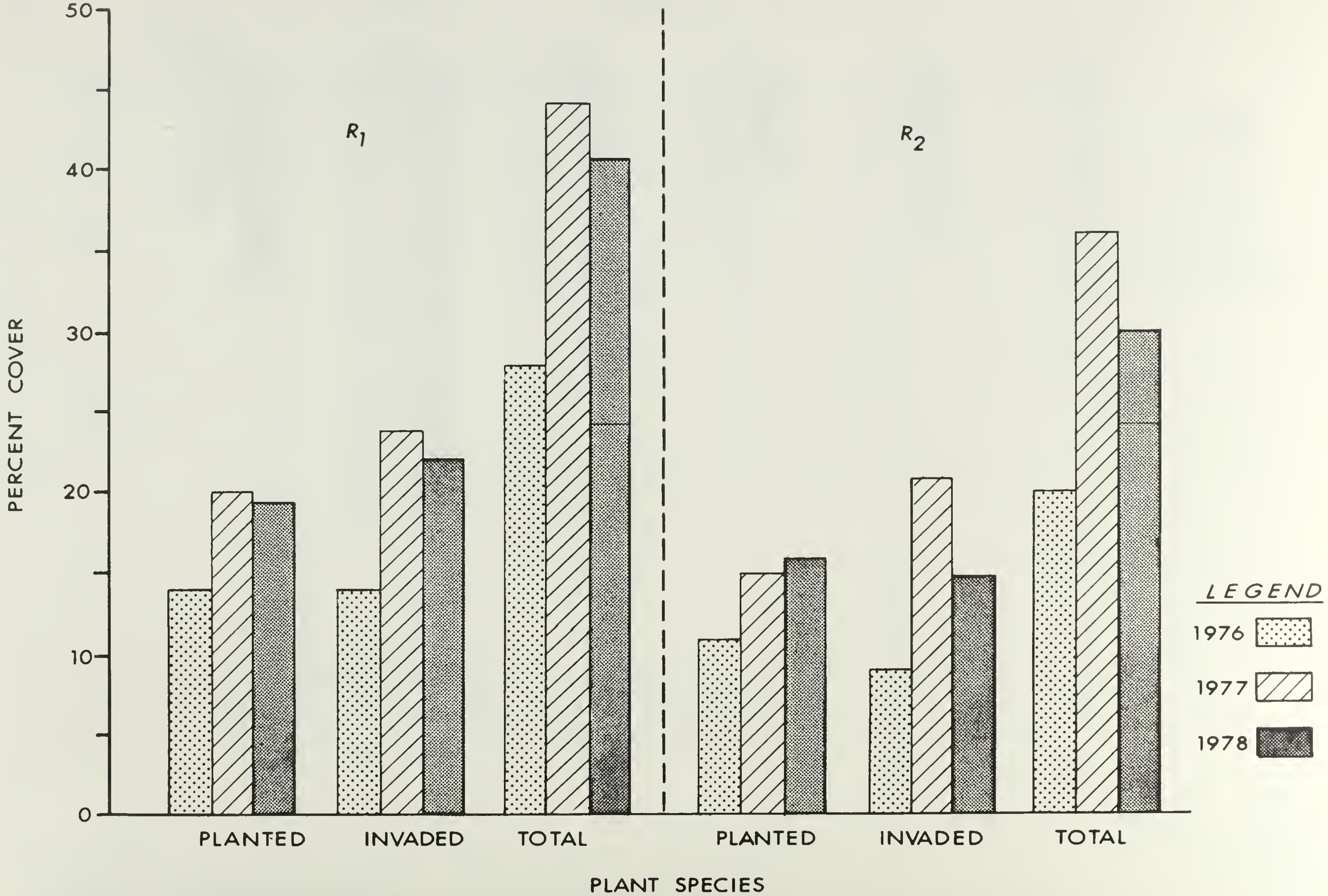


FIGURE 1-4. PERCENT COVER OF PLANTED, INVADED, AND TOTAL PLANT SPECIES AT THE RBOSC REVEGETATION SITE R_1 AND R_2 DURING 1976, 1977, AND 1978.

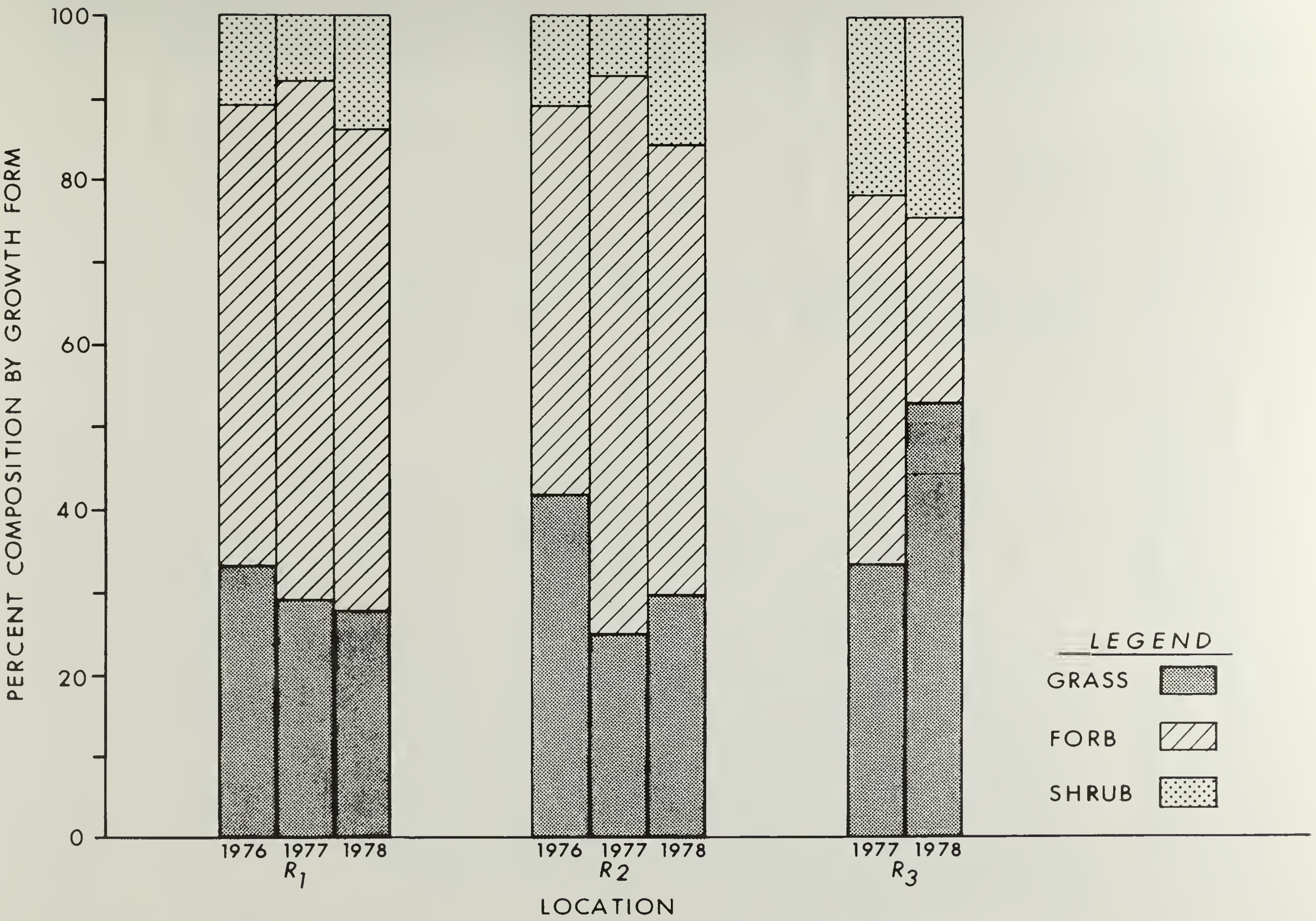


FIGURE 1-5. PERCENT COMPOSITION BY GROWTH FORM OF THE VEGETATION BASED ON PERCENT COVER IN THE RBOSC REVEGETATION SITES R_1, R_2 AND R_3, DURING 1976, 1977 AND 1978.

TABLE 1-4. ANALYSIS OF VARIANCE FOR PERCENT COVER FOR LOCATION R_1

Source of Variation	Degrees of Freedom	Mean Square	F-Value	Prob > F
Block	2	27.07		
Mulch	3	14.44	1.28	0.3640
Block x Mulch	6	11.30		
Fertilizer	3	20.78	4.43	0.0576
Block x Fertilizer	6	4.69		
Mulch x Fertilizer	9	14.81	1.43	0.2483
Block x Mulch x Fertilizer	18	10.38		
Species	42	1995.33	42.92	0.0001**
Block x Species	84	46.49		
Mulch x Species	126	25.15	1.38	0.0170*
Block x Mulch x Species	252	18.27		
Fertilizer x Species	126	60.46	4.98	0.0001**
Block x Fertilizer x Species	252	12.13		
Mulch x Fertilizer x Species	378	36.83	2.15	0.0001**
Block x Mulch x Fertilizer x Species	756	17.11		
Error	6192			
Corrected Total	8255			

---

* Significant at the 0.05 level

** Significant at the 0.01 level

cover by mulch and fertilizer treatments (Table 1-5) suggests that the average percent cover for each treatment is similar. It appears that mulch treatments do not affect total cover on northwest exposures after vegetation has established since the no mulch and straw treatments resulted in similar percent cover.

There is a significant difference among mulches for individual plant species (Appendix A-3). Luna pubescent wheatgrass, wheatgrass species, and green needlegrass each have significant differences at the 0.05 level for percent cover among mulch treatments.

Duncan's multiple range test (Duncan 1955) was used to compare 31 plant species to determine which means are different and which means are equivalent. The results of applying Duncan's multiple range test to the mean percent cover for the 31 plant species at location R_1 (Table 1-6) indicate that the plant species segregate into three distinct groups as compared to nine groups during 1977 (RBOSC 1978). Russian thistle forms a distinct group while Luna pubescent wheatgrass and wheatgrass species constitute a second group. The remaining group consists of grass, forb and shrub species which suggests that growth forms do not respond as a unit but rather each plant species responds independently. This trend for percent cover is similar to that found on R_1 during 1977 (RBOSC 1978).

For R_2 the ANOVA (Table 1-7) for percent cover indicates that significant differences at the 0.05 level exist among mulch treatments. A comparison of average percent cover by mulch and fertilizer treatments (Table 1-8) indicates that the no mulch and hydromulch treatments had the highest cover. Therefore, it appears that mulches do not affect total cover on southeast exposures after vegetation has established. There are also significant differences among mulches for individual species (Appendix A-4). The grass species appear to be most affected by mulch treatments. Significant differences at the 0.01 level also exist among species.

The results of Duncan's multiple range test for percent cover at location R_2 (Table 1-9) indicate that the 31 plant species segregate into seven distinct

TABLE 1-5. SUMMARY OF PERCENT COVER OF PLANTED, INVADED, AND TOTAL PLANT SPECIES IN EACH OF SIXTEEN TREATMENTS ON RBOSC REVEGETATION SITE R_1 DURING SEPTEMBER, 1978.

Mulch	Fertilizer	Planted	Invaded	Total
None	None	19	16	35
None	Fall	8	43	51
None	Spring	18	19	37
None	Fall-Spring	24	21	45
Hydromulch	None	26	3	29
Hydromulch	Fall	18	13	31
Hydromulch	Spring	16	22	38
Hydromulch	Fall-Spring	13	31	44
Straw	None	16	25	41
Straw	Fall	16	17	33
Straw	Spring	12	28	40
Straw	Fall-Spring	11	34	45
Netting & Straw	None	23	3	26
Netting & Straw	Fall	11	39	50
Netting & Straw	Spring	18	12	30
Netting & Straw	Fall-Spring	15	18	33

Average Percent Cover of Mulch Treatments

Mulch	Fertilizer	Planted	Invaded	Total
None		17	25	42
Hydromulch		18	17	35
Straw		14	26	40
Netting & Straw		17	18	35

Average Percent Cover of Fertilizer Treatments

Mulch	Fertilizer	Planted	Invaded	Total
	None	21	12	33
	Fall	13	28	41
	Spring	16	20	36
	Fall-Spring	16	26	42

TABLE 1-6. DUNCAN'S MULTIPLE RANGE TEST[1] FOR PERCENT COVER AT LOCATION R_1.

GROUPING[2]	MEAN	SAMPLE SIZE	SPECIES
A	20.485	192	*Salsola kali*
B	5,313	192	*Agropyron trichophorum*
B	3.997	192	*Agropyron* spp.
C	1.041	192	*Linum lewisii*
C	0.971	192	*Eurotia lanata*
C	0.955	192	*Atriplex canescens*
C	0.905	192	*Chrysothamnus nauseosus*
C	0.899	192	*Oryzopsis hymenoides*
C	0.732	192	*Stipa viridula*
C	0.562	192	*Chrysothamnus viscidiflorus*
C	0.534	192	*Astragalus cicer*
C	0.237	192	*Artemisia tridentata*
C	0.215	192	*Haplopappus nuttallii*
C	0.173	192	*Agropyron cristatum*
C	0.146	192	*Penstemon strictus*
C	0.131	192	*Bromus tectorum*
C	0.094	192	*Cryptantha sericea*
C	0.084	192	*Sitanion hystrix*
C	0.083	192	*Purshia tridentata*
C	0.064	192	*Kochia scoparia*
C	0.052	192	Unknown grass
C	0.033	192	*Astragalus* sp.
C	0.031	192	*Melilotus officinalis*
C	0.031	192	*Senecio multilobatus*
C	0.026	192	*Phleum pratense*
C	0.015	192	*Physaria floribunda*
C	0.010	192	*Poa* sp.
C	0.007	192	*Chaenactis douglasii*
C	0.005	192	*Hedysarum utahensis*
C	0.001	192	*Bromus* sp.
C	0.001	192	*Cercocarpus montanus*

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[1] Alpha Level = 0.5; DF =84; MS = 46.489

[2] Means with the same letter are not significantly different

TABLE 1-7. ANALYSIS OF VARIANCE FOR PERCENT COVER FOR LOCATION R_2

Source of Variation	Degrees of Freedom	Mean Square	F-Value	Prob > F
Block	2	14.90		
Mulch	3	14.28	5.00	0.0452*
Block x Mulch	6	2.86		
Fertilizer	3	8.78	2.76	0.1337
Block x Fertilizer	6	3.18		
Mulch x Fertilizer	9	2.77	1.09	0.4133
Block x Mulch x Fertilizer	18	2.53		
Species	42	762.05	69.90	0.0001**
Block x Species	84	10.90		
Mulch x Species	126	45.87	6.81	0.0001**
Block x Mulch x Species	252	6.74		
Fertilizer x Species	126	16.65	2.91	0.0001**
Block x Fertilizer x Species	252	5.73		
Mulch x Fertilizer x Species	378	6.31	0.95	0.7132
Block x Mulch x Fertilizer x Species	756	6.64		
Error	6192			
Corrected Total	8255			

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* Significant at the 0.05 level

** Significant at the 0.01 level

TABLE 1-8. SUMMARY OF PERCENT COVER OF PLANTED, INVADED, AND TOTAL PLANT SPECIES IN EACH OF SIXTEEN TREATMENTS ON RBOSC REVEGETATION SITE R_2 DURING SEPTEMBER, 1978.

Mulch	Fertilizer	Planted	Invaded	Total
None	None	14	20	34
None	Fall	15	16	31
None	Spring	10	17	27
None	Fall-Spring	6	31	37
Hydromulch	None	17	7	24
Hydromulch	Fall	21	9	30
Hydromulch	Spring	25	6	31
Hydromulch	Fall-Spring	21	14	35
Straw	None	19	8	27
Straw	Fall	15	7	22
Straw	Spring	17	12	29
Straw	Fall-Spring	14	17	31
Netting & Straw	None	11	10	21
Netting & Straw	Fall	11	13	24
Netting & Straw	Spring	13	12	25
Netting & Straw	Fall-Spring	15	12	27
Average Percent Cover of Mulch Treatments				
None		11	21	32
Hydromulch		21	9	30
Straw		16	11	27
Netting & Straw		13	12	25
Average Percent Cover of Fertilizer Treatments				
	None	15	11	26
	Fall	16	11	27
	Spring	16	12	28
	Fall-Spring	14	19	33

TABLE 1-9. DUNCAN'S MULTIPLE RANGE TEST[1] FOR PERCENT COVER AT LOCATION R_2.

GROUPING			MEAN	SAMPLE SIZE	SPECIES
	A		12.438	192	*Salsola kali*
	B		3.412	192	*Oryzopsis hymenoides*
	C		2.568	192	*Chrysothamnus nauseosus*
	C		2.539	192	*Agropyron* spp.
	D		1.490	192	*Agropyron trichophorum*
E	D		1.090	192	*Astragalus cicer*
E	D	F	1.068	192	*Linum lewisii*
D	G	F	0.617	192	*Stipa viridula*
E	G	F	0.578	192	*Chrysothamnus viscidiflorus*
E	G	F	0.517	192	*Purshia tridentata*
E	G	F	0.413	192	*Atriplex canescens*
E	G	F	0.344	192	*Artemisia tridentata*
	G	F	0.310	192	*Penstemon strictus*
	G	F	0.292	192	*Agropyron cristatum*
	G		0.246	192	*Eurotia lanata*
	G		0.146	192	*Senecio multilobatus*
	G		0.063	192	*Astragalus* sp.
	G		0.057	192	*Cryptantha sericea*
	G		0.035	192	*Melilotus officinalis*
	G		0.031	192	*Sitanion hystrix*
	G		0.028	192	*Physaria floribunda*
	G		0.027	192	*Bromus* sp.
	G		0.026	192	*Agropyron smithii*
	G		0.026	192	*Chaenactis douglasii*
	G		0.016	192	Unknown grass
	G		0.010	192	*Agropyron riparium*
	G		0.010	192	*Haplopappus nuttali*
	G		0.010	192	*Cercocarpus montanus*
	G		0.007	192	*Hedysarum utahensis*
	G		0.006	192	*Halogeton glomeratus*
	G		0.001	192	*Chenopodium* sp.

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[1] Alpha Level = 0.5; DF = 84; MS = 10.9

[2] Means with the same letter are not significantly different.

groups as compared to four groups during 1977 (RBOSC 1978). Russian thistle and Indian ricegrass form distinct groups. During 1978, Indian ricegrass emerged as a separate group as compared to 1977 when it was grouped with wheatgrass species or with Luna pubescent wheatgrass (RBOSC 1978). The remaining five groups consist of various combinations of life forms which suggests results similar to those discussed for R_1.

There were no significant differences among fertilizer treatments at locations R_1 and R_2 (Tables 1-4 and 1-7, respectively).

1.3.2 Biomass Data

Biomass was measured at R_1 and R_2 during the Fall of 1978. Biomass measurements were obtained by harvesting all vegetation present in each of the four permanent subplots within a treatment plot at each location. Vegetation was air-dried for 30 days and weighed. Biomass data are presented in Appendix A-5. A summary of the biomass data for three replicates (blocks) of each treatment at each location is presented in Appendix A-6.

Plant species which had the greatest biomass at R_1 and R_2 are the same species which had the largest percent cover (Table 1-10) (See Section 1.3.1). At R_1, Luna pubescent wheatgrass, wheatgrass species, Lewis flax, rabbitbrush species, and fourwing saltbush were the dominant planted species. At R_2, Indian ricegrass, Lewis flax, and rabbitbrush species were the planted species with the greatest biomass. Russian thistle contributed approximately 35-40 percent of the total biomass measured at either R_1 and R_2. A comparison of the vegetation composition based on biomass (Figure 1-6) indicates that shrubs constitute a greater portion of biomass than percent cover (Figure 1-5).

The long range objective of RBOSC revegetation efforts is to reestablish a plant community which has a productivity similar to native plant communities in the Tract C-a area. Baseline studies found that the upland sagebrush vegetation type similar to the community surrounding R_1 and R_2 has

TABLE 1-10. AVERAGE BIOMASS (kg/ha) OF PLANT SPECIES ON RBOSC REVEGETATION PLOTS, R_1 AND R_2 DURING 1978.

PLANT SPECIES	R_1	R_2
GRASSES		
Agropyron spp.	134	72
Agropyron trichophorum	267	63
Oryzopsis hymenoides	17	100
Stipa viridula	19	13
Agropyron smithii	-	1
Agropyron riparium	-	<1
Others	8	6
Total Grasses	445 (39)	<256 (26)
FORBS		
Salsola kali	442	348
Melilotus officinalis	<1	<1
Penstemon strictus	3	6
Linum lewisii	34	38
Astragalus cicer	10	23
Senecio multilobatus	<1	3
Physaria floribunda	<1	<1
Hedysarum utahensis	<1	<1
Others	12	9
Total Forbs	<505 (45)	<430 (45)
SHRUBS		
Chrysothamnus spp.	58	202
Purshia tridentata	2	11
Eurotia lanata	42	12
Atriplex canescens	64	29
Cercocarpus montanus	-	<1
Artemisia tridentata	11	21
Total Shrubs	177 (16)	<276 (29)
Planted Species	< 661	<594
Invaded Species	< 465	<368
Total	<1,126	<962

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*Number in parentheses is the percent represented by grasses, forbs, or shrubs for a given year.

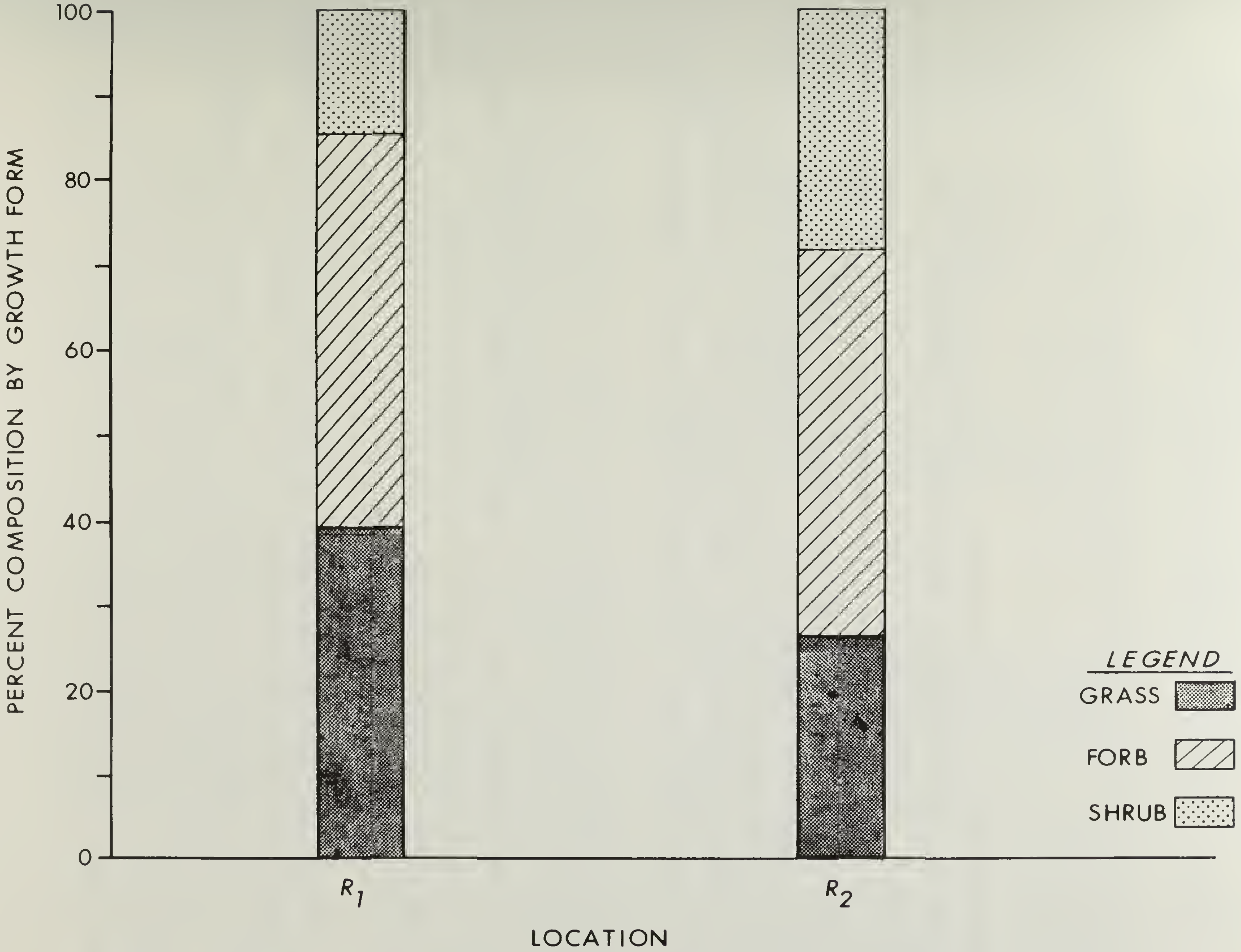

FIGURE 1-6. PERCENT COMPOSITION BY GROWTH FORM OF THE VEGETATION BASED ON BIOMASS ON THE RBOSC REVEGETATION SITE R_1 AND R_2 DURING 1978.

a productivity (grasses and forbs) of approximately 304 kg/ha (RBOSC 1977b). Biomass of planted grasses and forbs on R_1 and R_2 was 493 and 324 kg/ha, respectively. The biomass established on R_1 and R_2 through RBOSC revegetation efforts compares favorably with production measured during the baseline studies.

An ANOVA was performed to determine significant differences in biomass among mulch and fertilizer treatments. The results of the ANOVA for R_1 are presented in Appendix A-7; results for R_2 are presented in Appendix A-8.

For R_1, the ANOVA (Table 1-11) for biomass indicates that significant differences exist among mulches at the 0.05 level and among plant species at the 0.01 level. No differences exist among fertilizer treatments. A comparison of average biomass by mulch and fertilizer treatments (Table 1-12) indicates that the no mulch treatment produced the greatest total biomass as compared to the straw treatments which had the lowest. Of the three applied mulches, hydromulch had the greatest biomass of planted species while straw had the greatest biomass of invader species. There are significant differences among mulches for individual species, particularly the shrub species (Appendix A-7).

The results of Duncan's multiple range test for biomass at R_1(Table 1-13) indicate that the 27 species segregate into five groups as compared to the three groups for percent cover (Table 1-6). Russian thistle, Luna pubescent wheatgrass, and wheatgrass species each form separate groups; fourwing saltbush, winterfat, rubber rabbitbrush and Lewis flax form the fourth group. Thus, species are generally grouped similarly for percent cover and biomass although more distinct groups are apparent for biomass.

For R_2, the ANOVA (Table 1-14) for biomass indicates that no significant differences exist among mulch or fertilizer treatments; significant differences at the 0.01 level exist among species. A comparison of average biomass by treatments (Table 1-15) suggests that the straw mulches had the lowest total biomass while hydromulch had the greatest total biomass and biomass contributed by planted species. Thus, hydromulch appears to be most effective mulch to increase biomass production at R_1 and R_2. The lack of significant differences

TABLE 1-11 ANALYSIS OF VARIANCE FOR BIOMASS FOR LOCATION R_1

Source of Variation	Degrees of Freedom	Mean Square	F-Value	Prob > F
Block	2			
Mulch	3	199.63	6.01	0.0307*
Block x Mulch	6	33.20		
Fertilizer	3	59.46	0.49	0.7040
Block x Fertilizer	6	122.17		
Mulch x Fertilizer	9	115.88	0.79	0.6296
Block x Mulch x Fertilizer	18	146.74		
Species	42	15692.65	49.31	0.0001**
Block x Species	84	318.23		
Mulch x Species	126	316.34	3.48	0.0001**
Block x Mulch x Species	252	90.95		
Fertilizer x Species	126	486.95	2.73	0.0001**
Block x Fertilizer x Species	252	178.22		
Mulch x Fertilizer x Species	378	227.87	1.61	0.0001**
Block x Mulch x Fertilizer x Species	756	141.77		
Error	6192			
Corrected Total	8255			

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* Significant at the 0.05 level
** Significant at the 0.01 level

TABLE 1-12. SUMMARY OF BIOMASS (kg/ha) OF PLANTED, INVADED, AND TOTAL PLANT SPECIES IN EACH OF SIXTEEN TREATMENTS ON RBOSC REVEGETATION SITE R_1 DURING SEPTEMBER, 1978

Mulch	Fertilizer	Planted	Invaded	Total
None	None	763.4	395.0	1,158.4
None	Fall	452.4	861.3	1,313.7
None	Spring	794.5	470.6	1,265.1
None	Fall-Spring	958.9	666.0	1,624.9
Hydromulch	None	925.0	100.0	1,025.0
Hydromulch	Fall	825.8	302.4	1,128.2
Hydromulch	Spring	690.7	785.7	1,476.4
Hydromulch	Fall-Spring	522.2	717.3	1,239.5
Straw	None	555.6	516.7	1,072.3
Straw	Fall	567.6	327.5	895.1
Straw	Spring	386.0	600.2	986.2
Straw	Fall-Spring	398.2	629.7	1,027.9
Netting & Straw	None	897.4	85.1	982.5
Netting & Straw	Fall	476.2	725.5	1,201.7
Netting & Straw	Spring	647.2	258.7	905.9
Netting & Straw	Fall-Spring	643.8	366.8	1,010.6
Average Biomass of Mulch Treatments				
None		742.3	598.2	1,340.5
Hydromulch		740.9	476.3	1,217.2
Straw		476.8	518.5	995.3
Netting & Straw		666.2	359.0	1,025.2
Average Biomass of Fertilizer Treatments				
	None	785.4	274.2	1,059.6
	Fall	580.5	554.2	1,134.7
	Spring	629.6	528.8	1,158.4
	Fall-Spring	630.8	594.9	1,225.7

TABLE 1-13 DUNCAN'S MULTIPLE RANGE TEST[1] FOR BIOMASS AT LOCATION R_1.

GROUPING[2]		MEAN	SAMPLE SIZE	SPECIES
	A	46.847	192	*Salsola kali*
	B	26.673	192	*Agropyron trichophorum*
	C	13.430	192	*Agropyron* spp.
	D	6.398	192	*Atriplex canescens*
E	D	4.194	192	*Eurotia lanata*
E	D	3.959	192	*Chrysothamnus nauseosus*
E	D	3.341	192	*Linum lewisii*
E		1.974	192	*Chrysothamnus viscidiflorus*
E		1.769	192	*Stipa viridula*
E		1.563	192	*Oryzopsis hymenoides*
E		1.195	192	*Artemisia tridentata*
E		0.705	192	*Astragalus cicer*
E		0.371	192	*Cryptantha sericea*
E		0.349	192	*Haplopappus nuttallii*
E		0.336	192	*Agropyron cristatum*
E		0.255	192	*Penstemon strictus*
E		0.188	192	*Kochia scoparia*
E		0.180	192	*Purshia tridentata*
E		0.148	192	*Astragalus* sp.
E		0.127	192	*Sitanion hystrix*
E		0.114	192	Unknown grass
E		0.084	192	*Bromus tectorum*
E		0.066	192	*Phleum pratense*
E		0.041	192	*Senecio multilobatus*
E		0.017	192	*Melilotus officinalis*
E		0.017	192	*Physaria floribunda*
E		0.008	192	*Poa* sp.

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[1] Alpha Level = 0.5; DF=84; MS=318.23

[2] Means with the same letter are not significantly different

TABLE 1-14. ANALYSIS OF VARIANCE FOR BIOMASS FOR LOCATION R_2

Source of Variation	Degrees of Freedom	Mean Square	F-Value	Prob > F
Block	2	215.90		
Mulch	3	325.31	2.07	0.2058
Block x Mulch	6	157.18		
Fertilizer	3	17.76	0.18	0.9072
Block x Fertilizer	6	99.55		
Mulch x Fertilizer	9	118.19	1.53	0.2107
Block x Mulch x Fertilizer	18	77.16		
Species	42	6865.26	15.89	0.0001**
Block x Species	84	432.03		
Mulch x Species	126	620.50	3.32	0.0001**
Block x Mulch x Species	252	186.81		
Fertilizer x Species	126	171.60	1.48	0.0045**
Block x Fertilizer x Species	252	115.74		
Mulch x Fertilizer x Species	378	92.69	0.71	1.000
Block x Mulch x Fertilizer x Species	756	130.96		
Error	6192			
Corrected Total	8255			

** Significant at the 0.01 level

TABLE 1-15. SUMMARY OF BIOMASS (kg/ha) OF PLANTED, INVADED, AND TOTAL PLANT SPECIES IN EACH OF SIXTEEN TREATMENTS ON RBOSC REVEGETATION SITE R_2 DURING SEPTEMBER, 1978

Mulch	Fertilizer	Planted	Invaded	Total
None	None	606.7	648.8	1,255.5
None	Fall	767.7	401.2	1,168.9
None	Spring	311.6	552.3	863.9
None	Fall-Spring	173.1	707.4	880.5
Hydromulch	None	721.7	200.7	922.4
Hydromulch	Fall	803.4	267.2	1,070.6
Hydromulch	Spring	1,039.9	157.3	1,197.2
Hydromulch	Fall-Spring	1,092.3	403.3	1,495.6
Straw	None	567.9	164.8	732.7
Straw	Fall	557.3	169.5	726.8
Straw	Spring	610.3	389.2	999.5
Straw	Fall-Spring	434.5	381.5	816.0
Netting & Straw	None	471.7	371.2	842.9
Netting & Straw	Fall	460.5	273.8	734.3
Netting & Straw	Spring	477.1	211.1	688.2
Netting & Straw	Fall-Spring	430.0	383.5	813.5
Average Biomass of Mulch Treatments				
None		464.8	577.4	1,042.2
Hydromulch		914.3	257.1	1,171.4
Straw		542.5	276.2	818.7
Netting & Straw		459.8	309.9	769.7
Average Biomass of Fertilizer Treatments				
	None	592.0	346.4	938.4
	Fall	647.2	277.9	925.1
	Spring	609.7	327.5	937.2
	Fall-Spring	532.5	468.9	1,001.4

among mulches on R_2 as compared to R_1 may result from the better plant-water relations expected on a northwest exposure. Therefore, mulches appear not to be as critical on R_2 as results suggest for R_1, which has a southeast exposure.

The Duncan multiple range test for biomass at R_2 (Table 1-16) segregated the 29 plant species into six distinct groups as compared to seven groups for percent cover (Table 1-9). The size of the groups are almost identical with the exception that there is less differentiation among the less abundant grass, forb and shrub species which form the fifth and sixth groups.

1.3.3 Soils Data

Samples for soil moisture determinations were collected at R_1 and R_2 in June, August, and October, 1978. Soil moisture levels were generally similar between R_1 and R_2 with the exception of surface samples (o cm) which showed substantial variation among samples (Table 1-17). During a specific sampling period, soil moisture increased with soil depth but percent moisture varied at a given depth between seasons. Subsurface soils at the 30 and 45 cm depths decreased in soil moisture during August and October. Such decreases in soil moisture probably resulted from the lack of late summer rains during 1978 (Table 1-3) which limited soil recharge at the 30 and 45 cm depths, although recharge is evident at the 15 cm depth.

A comparison of soil moisture levels for June and September-October of 1976, 1977 and 1978 indicates that 1977 and 1978 subsurface soil values at both R_1 and R_2 were generally lower than those measured during 1976. (Figures 1-7 and 1-8, respectively). For R_1, June subsurface values are generally greater than September-October values except during 1977 when conditions were reversed (Figure 1-7). For R_2, subsurface moisture levels decreased from June to September-October during all three years (Figure 1-8).

TABLE 1-16. DUNCAN'S MULTIPLE RANGE TEST[1] FOR BIOMASS AT LOCATION R_2.

GROUPING			MEAN	SAMPLE SIZE	SPECIES
	A		33.682	192	*Salsola kali*
	B		17.531	192	*Chrysothamnus nauseosus*
	C		11.416	192	*Oryzopsis hymenoides*
D	C		7.274	192	*Agropyron* spp.
D	E		6.065	192	*Agropyron trichophorum*
D	E	F	3.341	192	*Linum lewisii*
D	E	F	2.878	192	*Atriplex canescens*
D	E	F	2.609	192	*Chrysothamnus viscidiflorus*
	E	F	2.098	192	*Astragalus cicer*
	E	F	2.073	192	*Artemisia tridentata*
	E	F	1.298	192	*Stipa viridula*
	E	F	1.161	192	*Eurotia lanata*
		F	1.070	192	*Purshia tridentata*
		F	0.619	192	*Penstemon strictus*
		F	0.478	192	*Agropyron cristatum*
		F	0.470	192	*Cryptantha sericea*
		F	0.287	192	*Senecio multilobatus*
		F	0.257	192	*Astragalus* sp.
		F	0.095	192	*Agropyron smithii*
		F	0.058	192	*Sitanion hystrix*
		F	0.042	192	*Bromus* sp.
		F	0.028	192	Unknown grass
		F	0.027	192	*Physaria floribunda*
		F	0.014	192	*Haplopappus nuttallii*
		F	0.003	192	*Chaenactis douglasii*
		F	0.003	192	*Melilotus officinalis*
		F	0.002	192	*Cercocarpus montanus*
		F	0.001	192	*Halogeton glomeratus*
		F	0.001	192	*Agropyron riparium*

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[1] Alpha Level = 0.5; DF=84; MS=432.03

[2] Means with the same letter are not significantly different.

TABLE 1-17. SOIL MOISTURE IN PERCENT WATER[1] FOR LOCATIONS R_1 AND R_2 DURING JUNE, AUGUST, AND OCTOBER 1978.

	SOIL DEPTH											
	0 cm			15 cm			30 cm			45 cm		
LOCATION R_1 Sample No.	June	August	October	June	August	October	June	August	October	June	August	October
1	3.39	3.47	9.51	6.28	8.55	7.90	8.98	9.08	7.48	10.23	10.38	7.62
2	3.26	3.73	8.70	8.04	5.57	6.93	9.84	7.34	7.11	11.01	8.13	7.48
3	2.97	3.05	12.97	8.23	6.20	9.79	9.99	7.76	10.13	9.51	8.84	10.91
Composite (S_1, S_2, & S_3)	3.21	3.42	10.39	7.52	6.77	8.21	9.60	8.06	8.24	10.25	9.12	8.67
LOCATION R_2	SOIL DEPTH											
1	2.59	1.86	4.87	10.62	3.95	6.38	12.11	4.91	5.80	13.17	5.62	6.43
2	2.67	2.75	7.20	13.38	4.73	6.38	13.58	7.18	8.27	14.00	7.20	8.51
3	2.50	2.38	7.43	8.89	4.47	6.75	12.71	6.25	7.34	13.95	6.88	7.53
Composite (S_1, S_2, & S_3)	2.59	2.33	6.50	10.96	4.38	6.50	12.80	6.11	7.14	13.71	6.50	7.49

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[1] Black (1965) $\frac{\text{(Weight of wet soil + tare) - (Weight of dry soil + tare)}}{\text{(Weight of dry soil + tare) - (tare)}}$

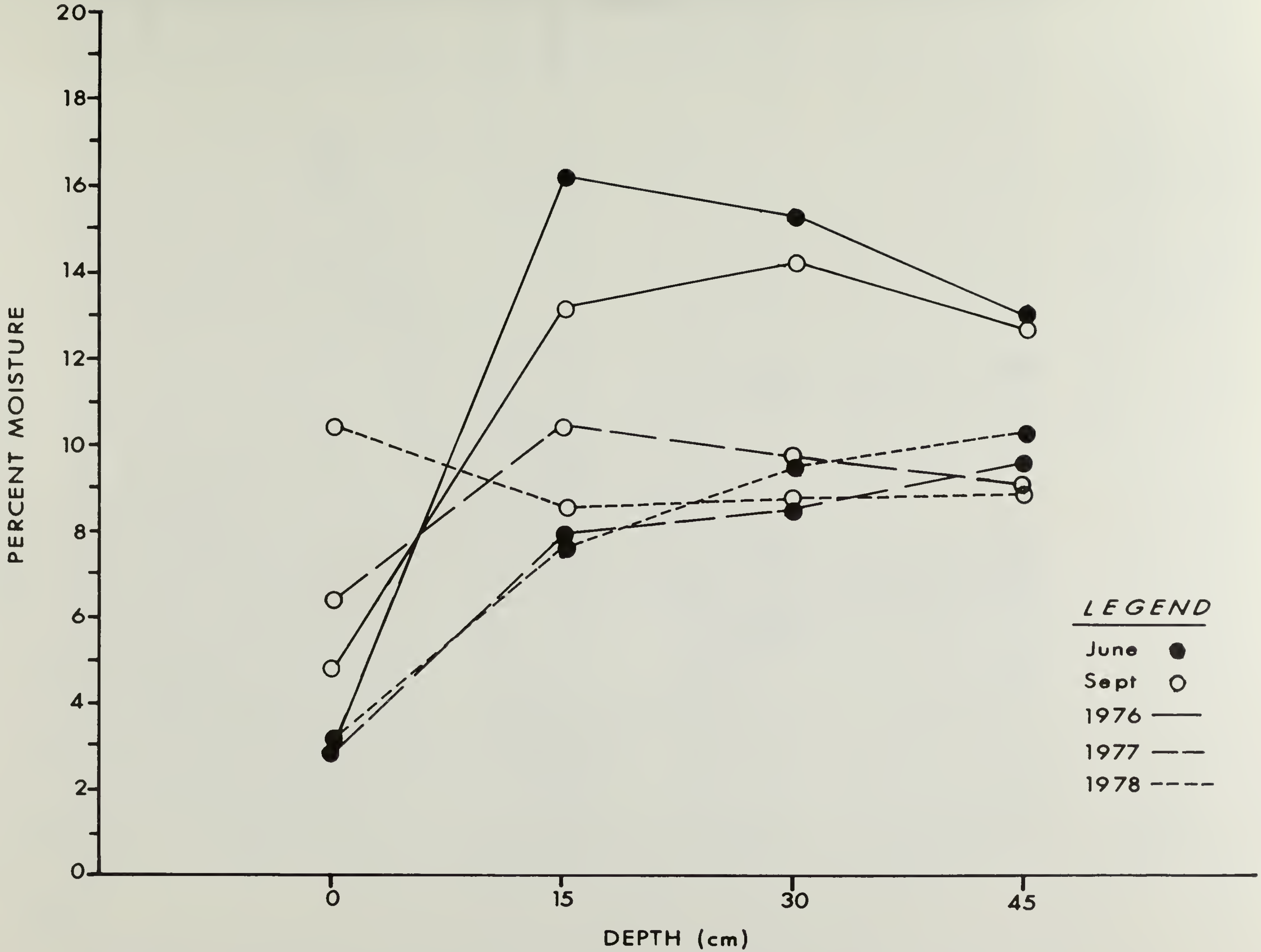

FIGURE 1-7. PERCENT SOIL MOISTURE MEASURED AT LOCATION R_1 IN JUNE AND SEPTEMBER-OCTOBER DURING 1976, 1977 AND 1978.

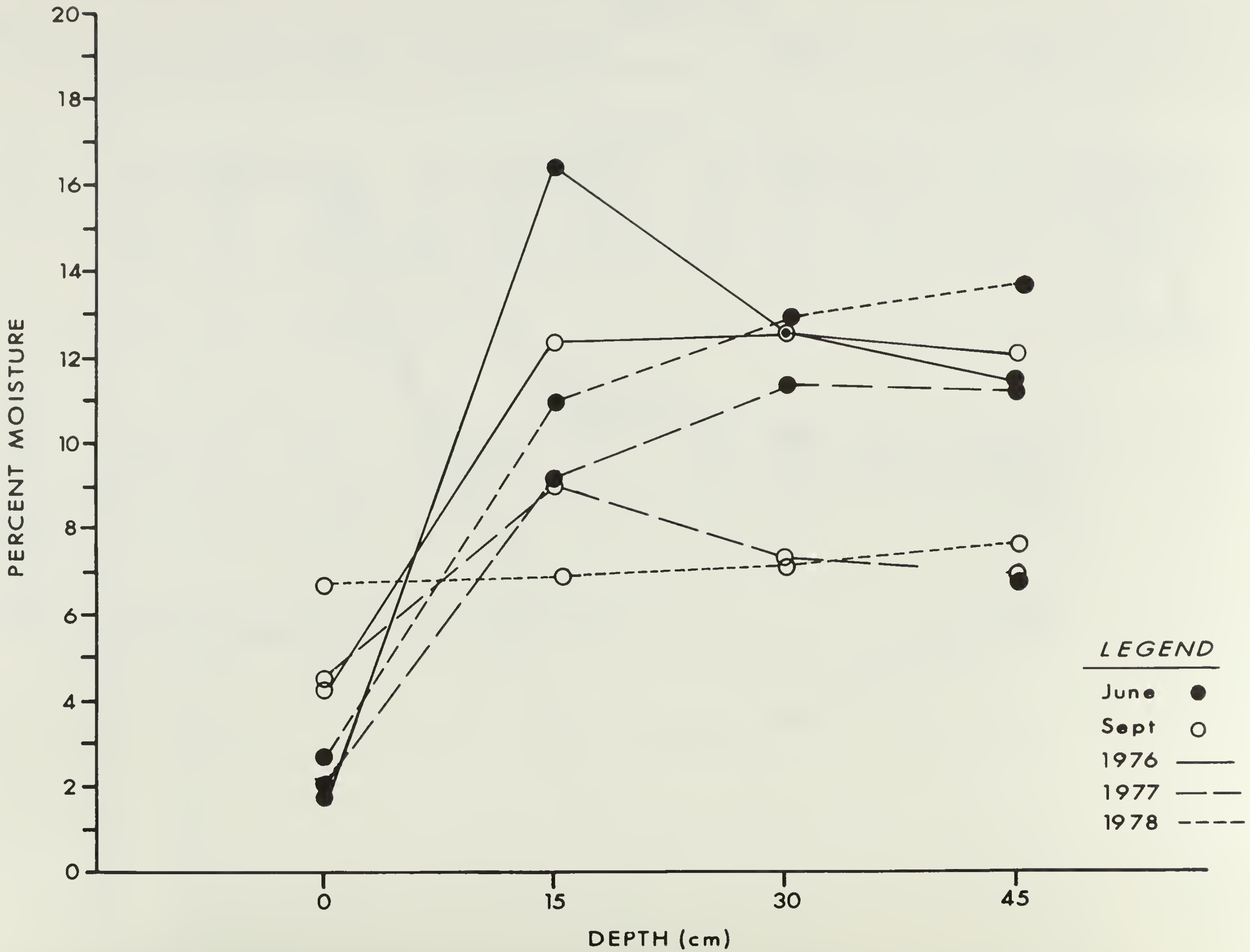

FIGURE 1-8. PERCENT SOIL MOISTURE AT LOCATION R_2 IN JUNE AND SEPTEMBER-OCTOBER DURING 1976, 1977, AND 1978.

1.4 Summary

Percent cover and biomass data were collected during Fall, 1978 at locations R_1 and R_2. Results of ANOVA for these data indicate that significant differences occur among species and among mulches. Fertilizer treatments did not cause significant differences.

After three growing seasons, there were fewer significant differences among mulches than during the first two years. At R_1 percent cover was approximately equal among the four mulches, although hydromulch had the highest percent cover of planted species. At R_2, mulch appears to be more important than at R_1 since a significant difference exists; hydromulch also had the highest percent cover of planted species.

Plants which had the greatest biomass at R_1 and R_2 are the same species which had the largest percent cover. The biomass established on R_1 and R_2 through experimental revegetation efforts compares favorably with production measured during the baseline studies.

After three years, changes in plant composition indicate that succession is occurring as expected. Invaded forb species, e.g., Russian thistle, are becoming less dominant as grasses and shrubs become more abundant. Percent cover was approximately equal to that existing in 1977.

The percent cover and biomass data indicate that the vegetation has successfully established at R_1 and R_2. Although species composition will continue to change as succession progresses, it appears that a stable plant community exists which consists of a diversity of native grasses, forbs, and shrubs similar to the surrounding vegetation. The successful plant establishment, obtained without supplemental irrigation during three years of average or below-average precipitation, suggests that revegetation can be accomplished in the Piceance Basin with little or no use of supplemental water.

SECTION 2.0 REVEGETATION EXPERIMENTS INITIATED IN 1976

2.1 Objectives

During RBOSC's commercial operations, processed shale will be produced as a by-product of surface retorting. This material may require surface disposal if the processed shale cannot be returned by slurry to the underground burned-retorts. RBOSC initiated the 1976 revegetation experiments to determine a feasible method to reestablish productive, self-sustaining wildlife habitat on processed shale disposal sites.

RBOSC has designed an artificial soil profile (RBOSC 1976) which, when placed on top of the processed shale, will inhibit capillary migration of toxic elements into the surface plant growth medium. The 1976 experiments were designed to investigate the effectiveness of the proposed artificial soil profile. The experimental treatments include substrate, mulch types, seeding intensity, and shrub establishment methods. A more detailed discussion of the objectives of the 1976 experiments was presented in the 1976 Revegetation Annual Report (RBOSC 1977a).

2.2 Methods

The 1976 revegetation site (R_3) is located on a southeast exposure north of site R_2. Eighteen treatment combinations were applied to 36 plots on R_3 in a factorial design. A detailed description of the methods used in the 1976 experiments was presented in Section 2.2 of the 1976 Revegetation Annual Report (RBOSC 1977a). Seedling emergence density, seedling survival density, and percent cover were estimated for each treatment during 1977; percent cover was measured in 1978. Supplemental irrigation was applied to R_3 during July-August 1977(first growing season) because of the extreme drought conditions (RBOSC 1978). No supplemental irrigation was applied during 1978.

Soil moisture measurements are made three times each year (June, August, October) by gravimetric techniques. Soil conductivity samples are collected in the Fall of each year and analyzed in a 2:1 soil - water extract. A detailed description of the soil studies methodology was presented in the 1976 Revegetation Annual Report (RBOSC 1977a).

An ANOVA is performed for each of the dependent variables. The ANOVA is a fixed model factorial design. A complete description of the fixed model factorial design and the statistical analyses is presented in the 1977 Revegetation Annual Report (1978).

2.3 Results

2.3.1 Percent Cover Data

Percent cover was measured at R_3 during September, 1978. The percent cover for each of the six permanent subplots within each treatment are presented in Appendix B-1.

A view of location R_3(Figure 2-1) indicates that vegetation reestablishment has been successful. The dominant species at R_3 include wheatgrass species, Manchar brome (Bromus inermis), Luna pubescent wheatgrass, Indian ricegrass, yellow sweetclover, winterfat, and fourwing saltbush (Appendix B-1). Total percent cover on R_3 increased by approximately 10 percent from 1977 to 1978 (Table 2-1). The increase in percent cover resulted from an increase in planted species; cover of invaded species decreased (Figure 2-2). Wheatgrass species, Manchar brome, Indian ricegrass, winterfat and fourwing saltbush showed the largest increase in cover. The forbs generally decreased in percent cover. The percent cover of desirable vegetation at R_3 (e.g., planted species) is greater than that found at R_1 or R_2 (Figure 1-4). Location R_3 contains less than one percent Russian thistle as compared to the 20 and 13% found on R_1 and R_2 (Tables 1-1 and 1-2 respectively). Native hay appears to limit the introduction of weedy species which are prevalent on the straw mulch plantings at R_1 and R_2. The 28 percent cover at R_3 exceeds the 10-25 percent cover estimated for upland sagebrush during baseline.

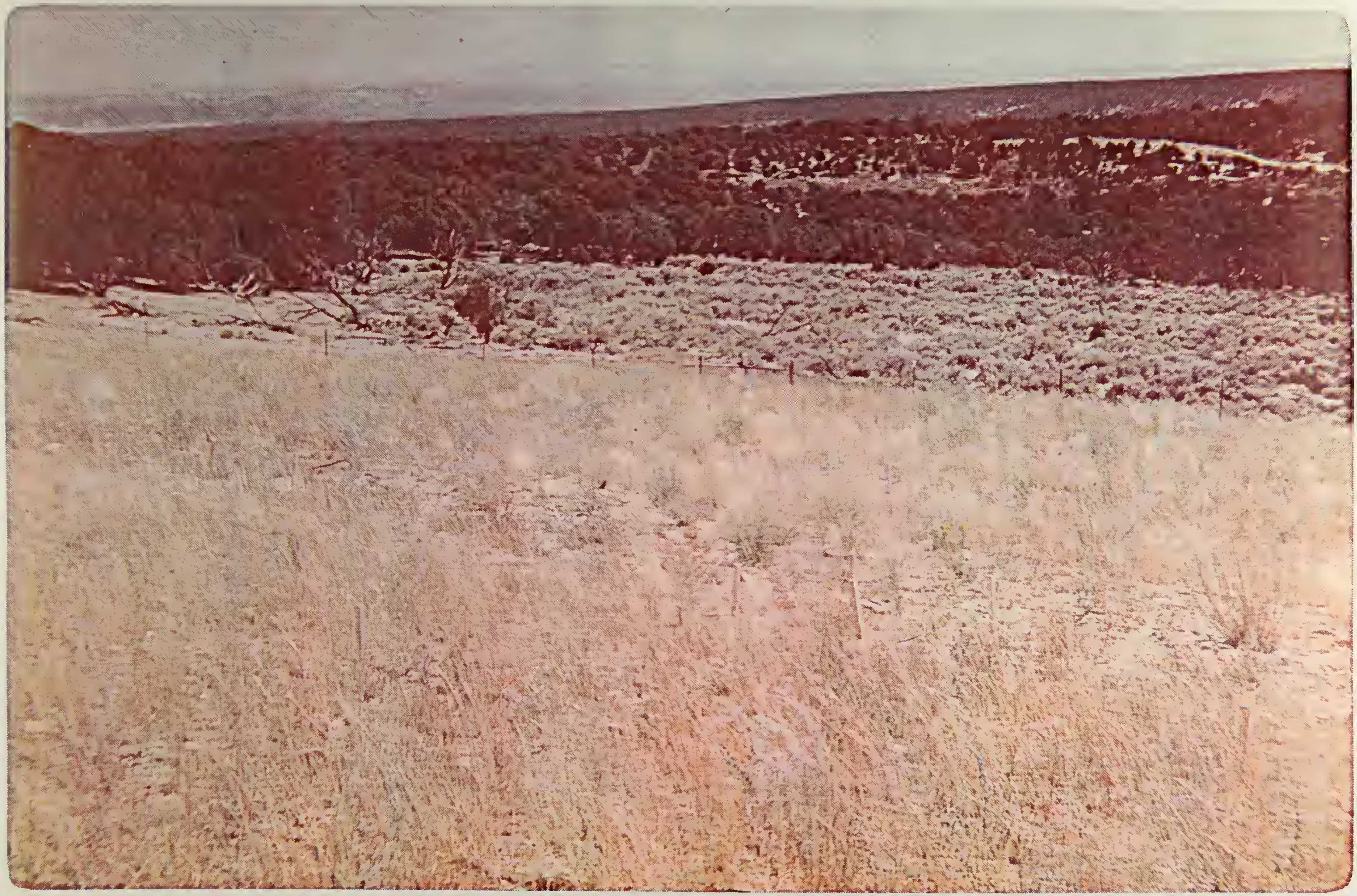

FIGURE 2-1. VIEW OF RBOSC REVEGETATION PLOT R_3 FROM THE SOUTHWEST CORNER OF THE PLOT.

TABLE 2-1. AVERAGE PERCENT COVER OF PLANT SPECIES PRESENT ON RBOSC REVEGETATION PLOT R_3 DURING FALL OF 1977 AND 1978

	1977	1978
Grasses		
Agropyron spp	2.4	7.1
Agropyron trichophorum	1.4	2.5
Bromus inermis	1.2	3.4
Bromus tectorum	0.7	0.1
Oryzopsis hymenoides	0.4	2.7
Stipa viridula	0.2	0.3
Others	< 0.1	0.4
Total Grasses	6.4(32)*	14.5(53)*
Forbs		
Melilotus officinalis	6.5	3.9
Salsola kali	0.9	0.4
Astragalus cicer	0.8	0.7
Physaria floribunda	0.3	0.1
Hedysarum utahensis	0.1	< 0.1
Penstemon strictus	0.1	0.1
Linum lewisii	0.1	0.2
Chrysanthemum leucanthemum	< 0.1	---
Others	0.3	0.2
Total Forbs	9.2(45)*	5.7(21)*
Shrubs		
Eurotia lanata	2.3	3.8
Atriplex canescens	1.2	2.4
Cercocarpus montanus	0.7	0.1
Purshia tridentata	0.4	0.3
Chrysothamnus spp	< 0.1	0.1
Artemisia tridentata	---	0.1
Atriplex gardneri	---	< 0.1
Atriplex bonnevillensis	---	0.1
Kochia prostrata	---	0.2
Camphorosma monospeliaca	---	0.1
Total Shrubs	4.7(23)*	7.3(26)*
Planted Species	18	28
Invaded Species	2	1
Total	20	29

---

* Number in parentheses is the percent represented by grasses, forbs, or shrubs.

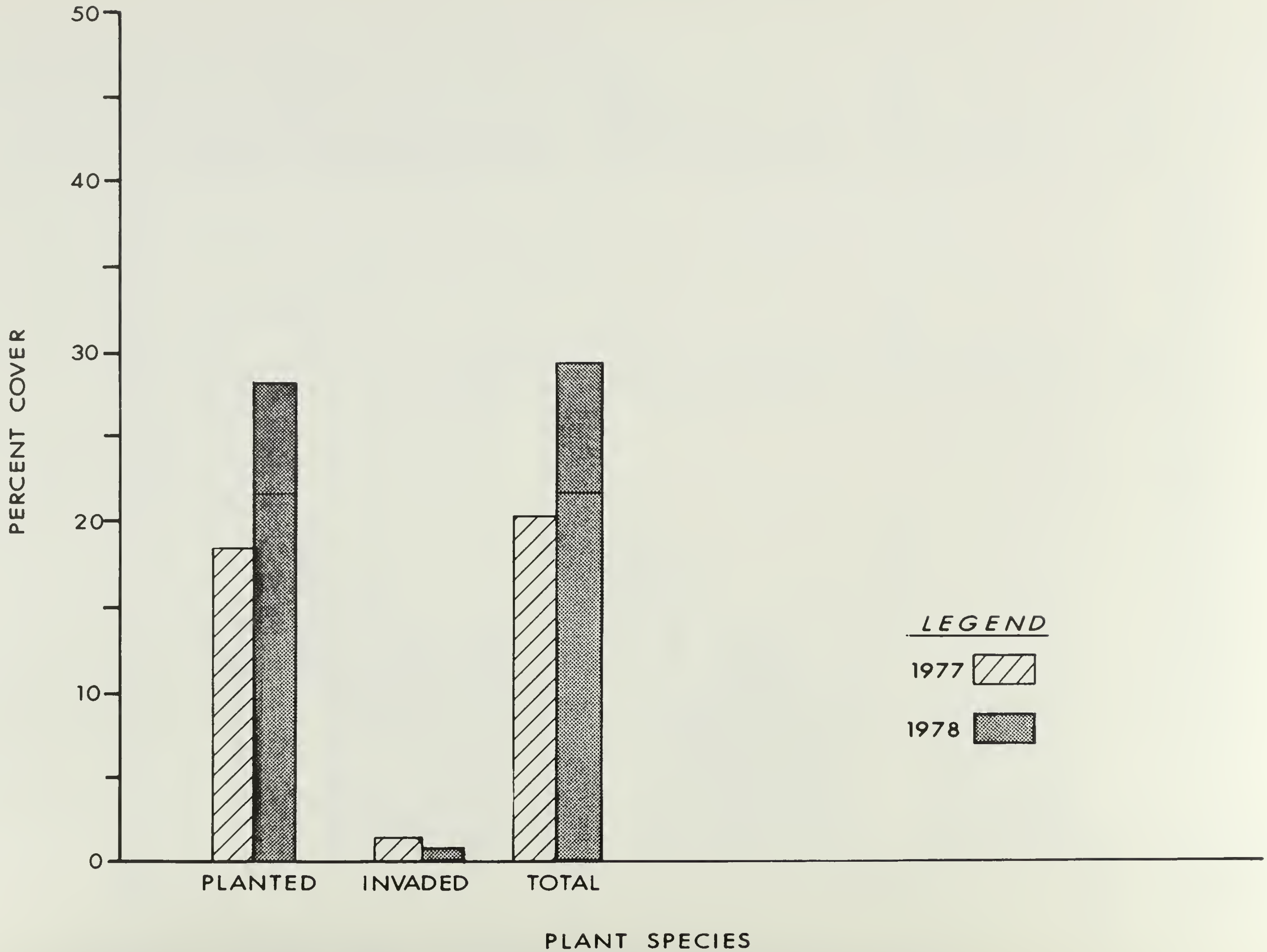

FIGURE 2-2 . PERCENT COVER OF PLANTED, INVADED, AND TOTAL PLANT SPECIES AT THE RBOSC REVEGETATION SITE R_3 DURING 1977 AND 1978.

A comparison of percent cover of plant species between the two substrate types for each mulch and seeding treatment is presented in Appendix B-2. Of the nine comparisons, the results for six of the processed shale treatments are generally equal to or greater than those for the no processed shale. Only the hydromulch/medium seeding, hydromulch/high seeding, and hay/medium seeding treatments had better results for no processed shale than processed shale. Any significant differences between the substrates are discussed later.

An ANOVA was performed to determine significant differences in percent cover at R_3 among treatments (Appendix B-3). Significant differences for individual species were most frequent among seeding treatments.

An ANOVA to test differences among treatments for total species (Table 2-2) indicates that only differences among plant species are significant at the 0.01 level. Differences among seeding treatments exist at the 0.07 level in comparison to the high level of significance (0.01) found during 1977 (RBOSC 1978). A comparison of percent cover (Table 2-3) indicates an increase in percent cover with increased seeding intensity; the medium and high intensities were approximately equal. The substrate and mulch treatments had approximately equal percent cover.

The results of Duncan's multiple range test for percent cover (Table 2-4) indicate that the 29 plant species occurring at R_3 segregate into five distinct groups. Grouping is not confined to growth forms since combinations of grass, forbs, and shrubs exist. Therefore, no response patterns are evident.

2.3.2 Containerized Shrub Seedling Data

Mortality, height, and diameter were measured during July and September, 1978 for the containerized seedlings planted at R_3 during June, 1977 (Appendix B-4). A summary of average height and average diameter of the

TABLE 2-2 ANALYSIS OF VARIANCE FOR PERCENT COVER FOR LOCATION R_3

Source of Variation	Degrees of Freedom	Mean Square	F-Value	Prob > F
Substrate	1	0.24	0.65[1]	
Mulch	2	0.54	1.45	0.4084
Substrate x Mulch	2	0.37		
Seeding	2	14.39	14.07	0.0664
Substrate x Seeding	2	1.02		
Seeding x Mulch	4	1.29	1.25	0.4178
Substrate x Seeding x Mulch	4	1.03		
Species	42	236.80	35.76	0.0001**
Substrate x Species	42	6.62		
Mulch x Species	84	2.03	1.34	0.0894
Substrate x Mulch x Species	84	1.51		
Seeding x Species	84	10.96	7.62	0.0001**
Substrate x Seeding x Species	84	1.44		
Seeding x Mulch x Species	168	1.56	0.69	0.9919
Substrate x Seeding x Mulch x Species	168	2.26		
Error	3870			
Corrected Total	4643			

** Significant at the 0.01 level

[1] Not significant at the 0.05 level

TABLE 2-3. SUMMARY OF PERCENT COVER OF PLANTED, INVADED, AND TOTAL PLANT SPECIES IN EACH OF EIGHTEEN TREATMENTS ON RBOSC REVEGETATION SITE R_3 DURING SEPTEMBER, 1978.

Substrate	Seeding Intensity	Mulch	Planted	Invaded	Total
Shale	Low	None	24	1	25
Shale	Medium	None	29	1	30
Shale	High	None	29	1	30
Shale	Low	Hydromulch	17	2	19
Shale	Medium	Hydromulch	34	1	35
Shale	High	Hydromulch	34	1	35
Shale	Low	Straw	25	1	26
Shale	Medium	Straw	32	1	33
Shale	High	Straw	32	1	33
No Shale	Low	None	23	3	26
No Shale	Medium	None	31	1	32
No Shale	High	None	29	<1	<30
No Shale	Low	Hydromulch	23	1	24
No Shale	Medium	Hydromulch	29	<1	<30
No Shale	High	Hydromulch	30	0	30
No Shale	Low	Straw	23	2	25
No Shale	Medium	Straw	27	2	29
No Shale	High	Straw	34	<1	<35
Average Percent Cover of Substrate Treatments					
Shale			29	1	30
No Shale			28	1	29
Average Percent Cover of Seeding Intensity Treatments					
	Low		22	2	24
	Medium		30	1	31
	High		31	1	32
Average Percent Cover of Mulch Treatments					
		None	28	1	29
		Hydromulch	28	1	29
		Straw	29	1	30

TABLE 2-4 . DUNCAN'S MULTIPLE RANGE TEST[1] FOR PERCENT COVER AT LOCATION R_3.

GROUPING[2]		MEAN	SAMPLE SIZE	SPECIES
	A	7.046	108	*Agropyron* spp.
	B	3.921	108	*Melilotus officinalis*
	B	3.833	108	*Eurotia lanata*
C	B	3.408	108	*Bromus inermis*
C	D	2.704	108	*Oryzopsis hymenoides*
	D	2.547	108	*Agropyron trichophorum*
	D	2.370	108	*Atriplex canescens*
	E	0.716	108	*Astragalus cicer*
	E	0.378	108	*Salsola kali*
	E	0.281	108	*Stipa viridula*
	E	0.260	108	*Purshia tridentata*
	E	0.242	108	*Linum lewisii*
	E	0.232	108	*Agropyron cristatum*
	E	0.231	108	*Kochia prostrata*
	E	0.139	108	*Atriplex bonnevillensis*
	E	0.139	108	*Chrysothamnus* spp.
	E	0.120	108	*Astragalus tegetarius*
	E	0.111	108	*Koeleria* sp.
	E	0.077	108	*Penstemon strictus*
	E	0.069	108	*Physaria floribunda*
	E	0.056	108	*Cryptantha sericea*
	E	0.046	108	*Artemisia tridentata*
	E	0.046	108	*Camphorosma monospeliaca*
	E	0.046	108	*Bromus tectorum*
	E	0.037	108	*Agropyron smithii*
	E	0.024	108	*Cercocarpus montanus*
	E	0.019	108	*Sitanion hystrix*
	E	0.010	108	*Atriplex gardneri*
	E	0.009	108	Unknown grass
	E	0.002	108	*Hedysarum utahensis*

---

[1] Alpha Level = 0.5; DF=42; MS= 6.621

[2] Means with the same letter are not significant different

containerized seedlings is included in Appendix B-4. The thirteen woody plant species being tested at R_3 are a joint effort of RBOSC and the U. S. Forest Service Shrub Science Laboratory in Provo, Utah.

Percent mortality of shrub seedlings through September 1978 ranged from 0-98 percent; most species had mortality rates of less than 40 percent (Table 2-5). Pinyon pine (Pinus edulis) had the highest mortality rate of 98 percent but most mortality had occurred during 1977. Gardner's saltbush (Atriplex gardneri) and mountain mahogany (Cercocarpus montanus) had the highest mortality recorded during 1978 (each 34%). Majority of the Gardner's saltbush mortality resulted from winter kill. Camphorosma monospeliaca and bitterbrush (Purshia tridentata) also had substantial winter losses.

Shrubs with mortality rates of less than 25 percent have been judged the most successful. These species include: native species - fourwing saltbush, winterfat, big sagebrush, and bitterbrush and introduced species - Atriplex bonnevillensis and Kochia prostrata (Table 2-5). Several of the preferred species, e.g., mountain mahogany, skunkbush, and globemallow (Sphaeralcea coccinea), had mortality ranging from 34-65 percent. Mortality in these latter species resulted from browse damage.

The greatest increases in shrub height during 1978 occurred prior to July (Table 2-6). Globemallow, Kochia prostrata, big sagebrush, and rubber rabbitbrush had substantial (greater than 100%) increases in height on both substrate types. Shrub species indicating negative growth were heavily browsed. Most species showed growth during the summer months (September data) but not as great as that recorded in July (Table 2-6).

During the August 1977 sampling, 108 individuals of four species of seeded shrubs were marked and measured for future comparison to the containerized seedlings. Measurements of the marked seeded shrubs and containerized shrubs made during September 1978 are presented in Table 2-7. No results are presented for mountain mahogany because either this species had a high mortality rate or could not be relocated during 1978.

TABLE 2-5. PERCENT MORTALITY (%) FOR THIRTEEN SPECIES OF CONTAINERIZED SEEDLINGS PLANTED AT RBOSC REVEGETATION PLOT R_3

	1977	1978		
	August	July[3]	September[4]	Total
Atriplex bonnevillensis[1]	11	0	0	11
Atriplex canescens[2]	0	0	0	0
Atriplex gardneri[1]	39	28	6	73
Artemisia tridentata[1]	6	3	0	9
Camphorosma monospleliaca[1]	11	14	3	28
Cercocarpus montanus[2]	31	16	18	65
Chrysothamnus nauseosus[2]	26	0	0	26
Eurotia lanata[2]	3	1	0	4
Kochia prostrata[1]	3	8	0	11
Pinus edulis[2]	88	5	5	98
Purshia tridentata[2]	12	10	3	25
Rhus trilobata[1]	33	0	6	39
Sphaeralcea coccinea[1]	31	0	3	34

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[1] Sample size = 36
[2] Sample size = 108
[3] Mortality occurring between August 1977 and July 1978.
[4] Mortality occurring between July 1978 and September 1978.

TABLE 2-6. CHANGE IN HEIGHT (inches) OF THIRTEEN CONTAINERIZED PLANT SPECIES ON RBOSC REVEGETATION JULY AND SEPTEMBER 1978.

	July[1]				September[2]			
Plant Species	Shale	%Change	Control	%Change	Shale	%Change	Control	%Change
Atriplex bonnevillensis	13.7(17)[3]	+101	11.7(15)	+ 70	14.2(17)	+ 4	13.3(15)	+14
Atriplex canescens	18.6(55)	+ 31	18.6(56)	+ 43	21.8(55)	+17	22.3(56)	+20
Atriplex gardneri	1.0(3)	- 50	6.0(6)	+233	1.2(5)	+20	2.0(5)	-67
Artemisia tridentata	9.7(17)	+142	11.7(16)	+134	15.9(17)	+64	11.6(16)	- 1
Camphorosma monospeliaca	2.2(13)	- 24	2.9(13)	+ 38	2.8(12)	+27	2.3(14)	-21
Cercocarpus montanus	2.1(21)	- 25	2.8(33)	- 13	1.7(15)	-19	2.0(22)	-29
Chrysothamnus nauseosus	11.0(41)	+124	11.3(39)	+157	11.9(41)	+ 8	11.4(39)	+ 1
Eurotia lanata	13.6(52)	+ 70	13.1(53)	+ 60	15.4(52)	+13	14.1(54)	+ 8
Kochia prostrata	19.2(15)	+200	18.8(15)	+242	24.3(16)	+27	21.7(15)	+15
Pinus edulis	1.3(6)	+ 18	2.0(2)	+100	1.0(2)	-23	1.0(1)	-50
Purshia tridentata	2.9(36)	- 17	4.3(45)	- 14	3.0(34)	+ 3	3.3(45)	-23
Rhus trilobata	4.4(12)	- 4	4.6(11)	- 23	4.0(11)	- 9	3.8(9)	-17
Sphaeralcea coccinea	9.4(13)	+262	10.0(12)	+376	7.5(13)	-20	9.1(11)	- 9

---

[1] % Change is the difference in height between August 1977 and July 1978.

[2] % Change is the difference in height between July 1978 and September 1978.

[3] Number in parentheses is sample size.

Containerized seedlings had a greater average height than seeded shrubs of the same species although the height of the containerized seedlings at planting must be considered (RBOSC 1978). The difference in height was greatest for fourwing saltbush but probably most important for bitterbrush since this species is more susceptible to browsing. Although seeded individuals of fourwing saltbush and winterfat were not as large as containerized seedlings, the heights achieved by the seeded individuals indicate that they are probably sufficiently vigorous to become permanently established. Therefore, direct seeding of these two species is a more cost effective method to establish these two shrub species.

TABLE 2-7. A COMPARISON OF AVERAGE SHRUB HEIGHT (inches) BETWEEN SEEDED SHRUBS AND CONTAINERIZED SHRUB SEEDLINGS AT LOCATION R_3 DURING SEPTEMBER 1978.

	No Processed Shale		Processed Shale	
	Seeded	Containerized	Seeded	Containerized
Atriplex canescens	14.5(38)[1]	22.3(56)	14.5(35)	21.8(55)
Eurotia lanata	11.5(50)	14.1(54)	11.8(44)	15.4(52)
Purshia tridentata	2.1(15)	3.3(45)	1.7(11)	3.0(34)

---

[1] Number is parentheses is sample size

The results of the shrub establishment investigations suggest that several methods will be necessary to establish those shrub species native to Tract C-a. Fourwing saltbush and winterfat can be successfully established by direct seeding and containerized seedlings but direct seeding is probably the more cost effective method of the two. Seed for winterfat and fourwing saltbush cost approximately $4 - 8/pound as compared to approximately $.75/unit for containerized shrub material. Bitterbrush and big sagebrush and other preferred browse species, e.g., skunkbush and globemallow, can be satisfactorily established with containerized shrubs. Neither of the methods investigated had successful results for mountain mahogany nor were containerized shrubs successful for pinyon pine. These two species are of particular concern since both provide important food and habitat for deer.

2.3.3 Soils Data

Soil samples for soil moisture determinations were collected at R_3 in June, August, and October, 1977. The soil moisture levels at R_3 (Table 2-8) were generally lower than those on R_2 (Table 1-16), although both are southeast-facing sites. A similar comparison existed during 1977 (RBOSC 1978). Subsurface moisture levels generally decreased during the growing season similar to the same trend found on R_1 and R_2 (Table 1-16). A comparison between soil moisture at R_3 during 1977 and 1978 (Figure 2-3) indicates that during 1977 October levels were greater than June. The reverse situation existed during 1978. The difference in moisture trends between 1977 and 1978 resulted from precipitation patterns during the specific year. During 1977, precipitation was greater during late summer while in 1978 precipitation was greatest during spring (Figure 1-3).

Soil samples for electrical conductivity determinations were collected at R_3 in November 1978. These samples were analyzed as described earlier. Results of the soil conductivity measurements at R_3 during 1978 are presented in Appendix B-5.

A comparison among the 1976, 1977 and 1978 soil conductivity determinations indicates that conductivity levels for all three years are generally similar (Table 2-9). Conductivity at the 50 cm depth decreased on both substrates. The soil conductivity levels measured at R_3 during 1976, 1977 and 1978 are not detrimental to plant growth and establishment (Richards 1954).

Table 2-9

AVERAGE ELECTRICAL CONDUCTIVITY OF SOILS SAMPLED
AT THREE DEPTHS (0, 25, 50 cm) AT RBOSC REVEGETATION
PLOT R_3 DURING FALL OF 1976, 1977, AND 1978

	Processed Shale			No Processed Shale		
Depth(cm)	1976	1977	1978	1976	1977	1978
0	.28	.20	.26	.26	.20	.28
25	.38	.26	.28	.31	.26	.27
50	.45	.50	.40	.56	.57	.42

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[1] mmhos/cm based on a 1:2 soil-water extract.

TABLE 2-8. SOIL MOISTURE IN PERCENT WATER[1] FOR LOCATIONS R_3 DURING JUNE, AUGUST, AND OCTOBER 1978.

Location R_3	SOIL DEPTH											
	0 cm			15 cm			30 cm			45 cm		
Sample No.	June	August	October	June	August	October	June	August	October	June	August	October
1	2.33	2.46	5.40	11.76	5.48	5.35	11.16	6.66	5.53	10.47	7.81	5.98
2	2.25	1.87	5.35	10.47	3.65	5.49	10.82	4.69	5.80	12.56	5.98	6.07
3	5.22	2.12	5.57	7.94	6.07	5.26	7.67	4.82	5.49	8.70	6.47	5.40
Composite (S_1, S_2, & S_3)	3.27	2.15	5.44	10.06	5.07	5.37	9.88	5.39	5.61	10.58	6.75	5.82

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[1] Black (1965) $\frac{\text{(Weight of wet soil + tare) - (Weight of dry soil + tare)}}{\text{(Weight of dry soil + tare) - (tare)}}$

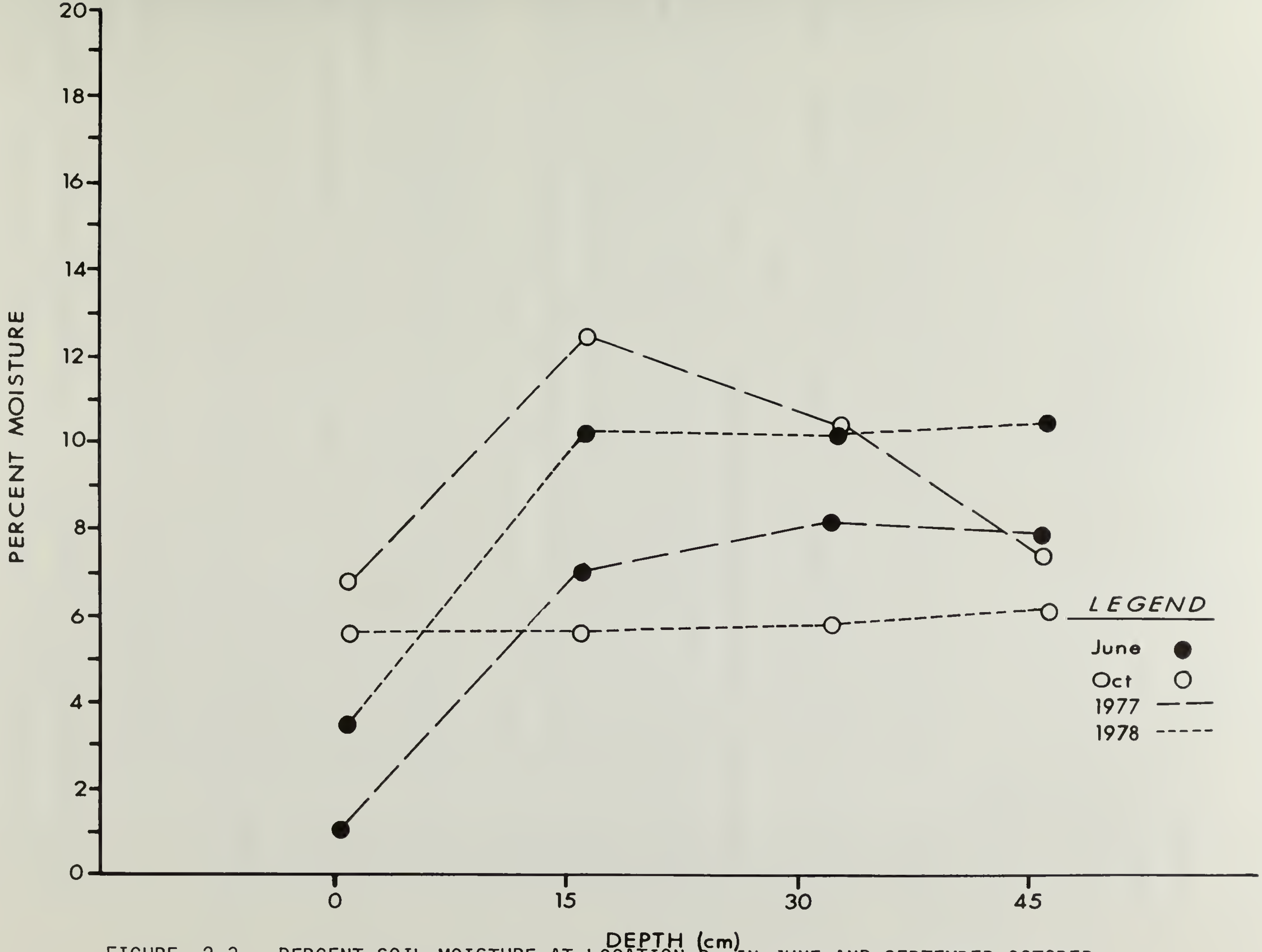

FIGURE 2-3. PERCENT SOIL MOISTURE AT LOCATION R_3 IN JUNE AND SEPTEMBER-OCTOBER DURING 1977 AND 1978.

No water leachate was available for collection at R_3 during 1978. The soil moisture data for R_3 (Table 2-8) suggest that the limited precipitation during 1978 did not allow sufficient percolation through the soil profile since subsurface soil moisture levels decreased during the growing season.

2.4 Summary

Percent cover and shrub establishment data were collected at R_3 during 1978. Results of the ANOVA for the percent cover data indicate that significant differences among treatments existed most frequently among seeding treatments. Significant differences among plant species at the 0.01 level were common.

Percent cover of plant species established at R_3 during the second year is greater than third year growth at R_1 or R_2 . The most obvious difference between the two experiments is the amount of Russian thistle on R_3 versus R_1 and R_2. Invaded species contributed less than 1 percent of the total cover present at R_3 in comparison to the 20 and 13 percent found on R_1 and R_2, respectively. Native hay tested at R_3 appears to reduce the introduction of undesirable species which are prevalent at R_1 and R_2.

The shrub establishment data suggest that several techniques are necessary to establish woody plant species native to Tract C-a. Direct seeding produced vigorous individuals of fourwing saltbush and winterfat which established successfully under adverse drought conditions on a southeast exposure. Containerized seedlings appear to be the most effective method to establish big sagebrush and bitterbrush. This method also had limited success for preferred browse species such as skunkbush and globemallow.

Soil conductivity measurements at R_3 during the first and second growing seasons indicate that resalinization of the artificial soil profile has not occurred. This indicates that the artificial soil profile is an effective method to inhibit upward capillary migration of toxic elements. The ANOVA for 1978 percent cover indicates that no significant differences exist between the two substrate types.

SECTION 3.0 CONCLUSIONS

3.1 Evaluation of the Experiments Initiated in 1975 and 1976

The objectives of the RBOSC experimental revegetation program were to investigate available revegetation technology and to determine the feasibility of successfully revegetating the disturbances expected to result from construction and waste disposal on Tract C-a. Thus, two experiments were designed to investigate reclamation procedures for surface disturbances (Locations R_1 and R_2) and one to investigate disturbances resulting from disposal of processed shale (Location R_3). The experimental programs were designed to collect three years of biological and soils data.

The results of the experiments initiated in 1975 and 1976 indicate that three years is the minimum length of time to assess the effectiveness of the tested treatments. Percent cover and biomass data appear to be the most useful of the data collected. Percent cover is a parameter which can be easily measured annually and provides a good indication of changes in species composition and species abundance which is necessary to evaluate successional changes. Biomass data are needed for comparison of revegetation results to baseline studies in accordance with Section 11 of the lease stipulations.

The emergence and survival density data were less useful in evaluating field results and it is suggested that the effort required to collect such data is excessive if not prohibitive. Identification of grass seedlings was also a substantial problem since a mixture of grasses was seeded. Similar information could be obtained in a more cost effective manner from the percent cover data.

The soil moisture measurements provided useful information in determining the drought conditions to which the seedlings were subjected. Continued collection of soil moisture data for R_1, R_2, and R_3 would probably not provide any information which cannot be interpreted from precipitation data.

Soil conductivity data at R_3 provide the most important means of evaluating the effectiveness of the artificial soil profile. It is essential that annual conductivity measurements be continued at R_3 to determine the effectiveness of the artificial soil profile over the long term.

Revegetation technology investigated during the three-year program included:

- Plant species adaptability (R_1, R_2, R_3)
- Mulch type (R_1, R_2, R_3)
- Timing of fertilizer application (R_1, R_2)
- Aspect (R_1, R_2)
- Substrate type (R_3)
- Seeding intensity (R_3)
- Shrub establishment techniques (R_3)

The success obtained using a mixture of grasses, forbs, and shrubs is encouraging since it appears that a diverse plant community can be achieved more rapidly in comparison to a planting of only grasses and forbs. The experimental results also indicate that numerous species can be used successfully to revegetate disturbances on Tract C-a although slope aspect should be considered when selecting a seed mixture.

The results indicate that there are differences in plant germination and establishment among the mulches tested and use of mulch improves success. The timing of fertilizer application does not appear to significantly affect establishment but the results indicate that fertilizer does enhance establishment of weedy species on disturbed areas.

Seeding rate appears to be the most important single factor in determining revegetation success.

Shrub establishment investigations suggest that a combination of plantings may be productive in establishing shrubs on Tract C-a. Winterfat and fourwing saltbush can be most economically grown by direct seeding. Big sagebrush and bitterbrush can be grown successfully from containerized seedlings.

The results obtained to date at R_3 indicate that an artificial soil profile is a feasible method to establish native vegetation on a processed shale disposal pile. The three to four foot profile provides a growth medium with sufficient depth and an acceptable chemical quality to support plant species similar to existing vegetation on Tract C-a.

3.2 Recommendations for Implementation of Revegetation Technology

Based on the results obtained from the RBOSC experimental program, the following are recommendations for revegetation of disturbances on Tract C-a.

- Seed mixtures should include grass, forb and shrub species.
- Indian ricegrass should be limited to mixtures for seeding south and southeast exposures.
- Winterfat and fourwing saltbush should be directly seeded.
- Seed should be planted at a drilling rate of 20 pounds/acre or greater.
- Hydromulch applied at a rate of 1,500 pounds/acre is the preferred mulch.
- If a natural mulch is required, native hay is preferable to straw.
- Fertilizer can be applied at any time of year; spring fertilization may reduce the benefit of fertilizer to weedy species.
- Use of an artificial soil profile atop processed shale will permit establishment of native vegetation.
- Bitterbrush and big sagebrush be planted as containerized seedlings; establishment of big sagebrush may be sufficent from invasion from adjacent areas.

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